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TITLE: Biomonitoring and Hazard Assessment Evaluation of  
Contaminated Groundwater at Aberdeen Proving Ground-  
Edgewood Area Beach Point Peninsula

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Near-field (ULINE model) and far-field (dye-tracer model) screening level dilution models were run to estimate the dilution of the groundwater discharge plume in the Bush River. The model analyses showed that a near-field dilution level of approximately 42:1 for the application of Maryland's acute aquatic life criteria and a near-field dilution level of 168:1 for the application of chronic criteria would occur. When the dilution factors were applied to groundwater quality at Beach Point, none of the heavy metals or chlorinated aliphatic compounds exceeded Maryland's current acute or chronic aquatic life criteria.

### 14. SUBJECT TERMS (Cont)

ULINE, far-field dilution model, dye tracer model, acute aquatic life criteria, and chronic aquatic life criteria.

FORWARD

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P. T. Burton  
Principal Investigator's Signature

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The contractor, The University of Maryland System, hereby certifies that, to the best of its knowledge and belief, the technical data delivered herewith under Contract No. DAMD17-92-C-2066 is complete, accurate, and complies with all requirements of the contractor.

Date: August 22, 1994

Name and Title of Certifying Official:

  
Dennis T. Burton, Ph.D  
Senior Research Scientist

## EXECUTIVE SUMMARY

The primary objective of the study was to evaluate the use of several biomonitoring systems for assessing contaminated groundwater. Contaminated groundwater, which contained multiple heavy metals and chlorinated aliphatic hydrocarbons, was studied. The contaminated groundwater was withdrawn from the lower depths of the surficial aquifer at Beach Point which is located in the Canal Creek Area of the U.S. Army Aberdeen Proving Ground-Edgewood Area, Aberdeen, MD. Groundwater was withdrawn from well CC-33B, which is the most the highly contaminated well at Beach Point. A hazard assessment of the groundwater release into the Bush River was performed using the biomonitoring results.

### Biomonitoring Evaluation

Several EPA priority pollutant heavy metals were found in the groundwater at Beach Point. The concentrations of cadmium, copper, nickel, and zinc exceeded one or more of EPA's numerical water quality criteria for the specific metal. A number of chlorinated aliphatic compounds were also found in the groundwater, several of which are EPA priority pollutants. The chlorinated aliphatic organics that occur at the lower depths of the aquifer may be present as a residual denser-than-water nonaqueous phase liquid (DNAPL). Of the organics present in the groundwater, none had octanol water partition coefficients ( $\log K_{ow}$  or  $\log P$ )  $>3$ ; thus, bioaccumulation was not a potential toxicological problem.

An array of nine biomonitoring systems integrated into a tiered hazard framework was evaluated during a 9-month study. The biomonitoring systems included a number of endpoints. The pH of the groundwater from well CC-33B was 4 ( $\pm 0.1$ ); thus, many of the assays were conducted at both pH 4 and pH 7. The toxicity at pH 7 was studied so that the data could be used in the hazard assessment of the groundwater as it entered the Bush River which has pH values close to the neutral range.

Toxicity was detected at various groundwater concentrations by 7 of 9 biomonitoring systems. The Ames assay for mutagenicity was negative in all cases (1, 10, and 100% groundwater by volume). Japanese medaka (*Oryzias latipes*) growth was not affected by 9 months of exposure to 1 and 10% groundwater by volume in a chronic histopathology assay. No significant lesions were found in the Japanese medaka exposed to groundwater concentrations up to 10% groundwater by volume (highest concentration studied). A positive response was found for 100% groundwater in a sister chromosome exchange (SCE) assay for DNA damage when the groundwater sample was concentrated  $\approx 50,000X$ . The SCE assay was negative for unconcentrated 100% groundwater. The positive SCE response in the 50,000X concentrated sample was

judged not to be important to aquatic organisms in the receiving stream.

The lowest concentration of groundwater that caused no observable adverse effect (NOEC) at pH 4, in the test systems in which the NOEC value could be determined, was 10% groundwater by volume. A NOEC of 10% groundwater by volume occurred in 3 out of 4 tests in both a 7-d cladoceran (Ceriodaphnia dubia) and a 96-h frog (Xenopus laevis) embryo teratogenesis assay - Xenopus (FETAX); it occurred once in a 7-d fathead minnow (Pimephales promelas) test. The NOEC concentration was higher at pH 7 in both the fathead minnow and FETAX assays. The 10% groundwater by volume NOEC for the cladoceran at pH 4, however, did not change when the organism was exposed to buffered groundwater at pH 7.

When estimated maximum acceptable toxicant concentrations (MATC) were established, the data for alga (Selenastrum capricornutum), invertebrate (C. dubia), and fish (P. promelas) used in the biomonitoring study suggested that the groundwater would not be harmful at a concentration of 10% groundwater by volume. Likewise, no genotoxicity, developmental toxicity, or chronic histopathology occurred at 10% groundwater by volume. Thus, the biomonitoring data suggested that chronic toxicity may not occur in the Bush River at a dilution of 10:1. Chronic toxicity was predicted to occur in the Bush River if the groundwater entered the receiving stream at the concentrations which occur in well CC-33B.

#### Hazard Assessment Evaluation

A number of worst-case assumptions were made for the Beach Point hazard assessment when sufficient data were not available. The following assumptions were made for the calculation of the estimated discharge rate of the surficial aquifer into the Bush River. The surficial aquifer was considered to be homogeneous, characterized by isotropic flow conditions. The average saturated thickness of the aquifer was assumed to be 18.8 m (61.8 ft). The aquifer was assumed to discharge the entire length of the Beach Point Peninsula fronting the Bush River; a more realistic estimate of length of discharge from Beach Point is probably one third to one half, rather than the entire length.

With regard to the contaminant concentrations in the groundwater, the assumption was made for heavy metals that no retardation occurred via adsorption onto solid surfaces or trapping by clays through ion exchange. It was also assumed that no precipitation of the metals occurred when the pH shifted from 4 to neutrality when the groundwater entered the receiving stream. The assumption was made for the DNAPLs that no abiotic (chemical) or biotic (microbial) transformations occurred.

It was also assumed that the heavy metals and residual DNAPLs were homogeneously mixed throughout the complete aquifer at the highest concentration (not the average concentration) measured during the course of the study. It was assumed that the maximum concentrations of materials would not increase above those currently present in well CC-33B since the original sources of the contaminants were not longer present. The assumption was made that the highest concentrations of the heavy metals and chlorinated aliphatics in the aquifer all moved through the sediments into the Bush River without any biotransformations or other physical/chemical transformations occurring in the sediment or water column of the Bush River.

When the above assumptions were used in the hazard assessment, the groundwater may be considered to be a potentially hazardous material to the benthic biota of the Bush River. The hazard to water column aquatic biota would rapidly dissipate as the groundwater materials mix in the receiving stream. Because the potential water quality impacts were judged to be minimal, a mixing zone approach by the State of Maryland which allows for local exceedences of water quality standards may be pursued. The State of Maryland Code (COMAR) allows for a mixing zone on a case-by-case basis. Pollutant concentrations within a mixing zone may exceed the specified water quality standards within a localized vicinity of an outfall.

Near-field (ULINE model) and far-field (dye-tracer model with input data originally obtained for the Bush River) EPA-approved screening level dilution models were run to estimate the dilution of the groundwater discharge plume in the Bush River. The concentrations of the groundwater hazardous substances were estimated for the near-field and far-field in the Bush River using the mixing zone requirements of the State of Maryland.

The model analyses showed that a total near-field dilution (near-field dilution corrected for the influence of far-field dilution) of approximately 42:1 for the application of the State's acute aquatic life criteria and a near-field dilution level of 168:1 for the application of chronic criteria would occur. Thus, contaminants introduced via Beach Point groundwater into Bush River receiving waters at a concentration of 42  $\mu\text{g/L}$  would be diluted locally to a concentration of approximately 1  $\mu\text{g/L}$  or less. When the dilution factors were applied to groundwater quality at Beach Point, none of the heavy metals or chlorinated aliphatic compounds exceeded Maryland's current acute or chronic aquatic life criteria. The dilution study showed that detectable concentrations of some of the chlorinated organics would occur in the receiving stream when the conservative assumptions concerning the groundwater contaminants were used in the model.

Although an argument can be made for a mixing zone, it is highly unlikely that the contaminant loads assumed in the near-field dilution model will ever occur in the Bush River. A refinement of the conservative assumptions used in the hazard assessment would reduce the uncertainty regarding the volume of the discharge as well as the concentration of contaminants that may enter the receiving stream.

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## SECTION 1

### INTRODUCTION

The primary goal of ecotoxicological testing is to predict the effects of chemicals (single elements, compounds, and mixtures) and other stressors (e.g., heated wastewater, suspended solids, etc.) on the long-term health of individual organisms, populations, communities, and ecosystems. There is no perfect short-term (acute) or long-term (chronic) toxicity test which allows one to predict with certainty the effects of a single toxicant (not to mention a complex mixture of contaminants) on ecosystems. Although perfect prediction is not attainable (Barnhouse et al., 1986), a well selected array or battery of biomonitoring assays integrated into a tiered hazard assessment approach can be used to maximize predictability of adverse pollutant effects to aquatic ecosystems (for ex., see Dutka and Kwan, 1988; National Research Council, 1981; Schaeffer and Janardam, 1987).

The selection of an appropriate tier of hazardous assessment biomonitoring tests is based on the problem to be solved (Cairns, 1990; Dickson et al., 1979; Mackay et al., 1989). Single species assays are the most widely used hazard assessment systems (for ex., see Cairns, 1986; Herricks and Schaffer, 1985; Rand and Petrocelli, 1985). Hazard assessment schemes may also incorporate multispecies microcosm tests and ecosystem level simulations in their protocols. Single species toxicity tests, multispecies microcosm tests, and ecosystem level simulations all have advantages and limitations (Neuhold, 1986). The U.S. Army Biomedical Research and Development Laboratory's (USABRDL) Research Methods Branch uses a hazard assessment biomonitoring testing tier which is composed primarily of an array of single species assays.

The University of Maryland in collaboration with USABRDL is evaluating the use of several biomonitoring systems for assessment of potentially contaminated groundwater and sediment-associated contaminants at U.S. Army installations. The current report summarizes an evaluation of contaminated groundwater which contained multiple heavy metals and chlorinated aliphatic hydrocarbons. The contaminated groundwater was withdrawn from the surficial aquifer at Beach Point which is located in the Canal Creek Area of the U.S. Army Aberdeen Proving Ground-Edgewood Area, Aberdeen, MD. The definitive experimental phase of the study was conducted over a 9-month period from February 25, 1993 to December 6, 1993. In addition to the primary goal of the study to evaluate the performance of the biomonitoring systems, the biomonitoring results were also used in a hazard assessment of the groundwater release in the Bush River.

## SECTION 2

### OBJECTIVES OF STUDY

The primary objectives of the study were to:

- 1) Evaluate the acute toxicity of the groundwater using the 5- and 15-min Microtox® procedure (Photobacterium phosphoreum bioluminescent activity) and the 24-h LC50 Rotifer Toxkit™ (Brachionus rubens) screening test. In addition, the following acute bioassays were also performed: algal (Selenastrum capricornutum) 96-h EC50 growth test, cladoceran (Ceriodaphnia dubia) 48-h LC50, fathead minnow (Pimephales promelas) 96-h LC50, and Japanese medaka Oryzias latipes) 96-h LC50.
- 2) Evaluate chronic toxicity using the 96-h EC50 algal (S. capricornutum) growth test, 7-d cladoceran (C. dubia) survival and reproduction test, and 7-d fathead minnow (P. promelas) survival and growth test.
- 3) Determine the genotoxicity potential of unconcentrated and concentrated samples of the groundwater using the Ames assay and Sister Chromatid Exchange assay.
- 4) Determine the developmental toxicity potential of the groundwater using the frog (X. laevis) embryo teratogenesis assay - Xenopus (FETAX).
- 5) Determine the chronic histopathological potential of the groundwater using a 9-month Japanese medaka (O. latipes) growth and chronic histopathology test.
- 6) Quantify the major chemicals present in the groundwater and monitor the general water quality of the groundwater.

A secondary objective of the study was to use the biomonitoring data obtained in the biomonitoring system evaluations to assess the potential hazard of the groundwater as it moved into an aquatic ecosystem (Bush River).

## SECTION 3

### BEACH POINT SITE DESCRIPTION

#### 3.1 Physiographic Setting

Beach Point is a peninsula located in the Canal Creek Area of the U.S. Army Aberdeen Proving Ground-Edgewood Area (APG-EA), Aberdeen, MD. The peninsula is bounded by the Bush River on the southeast and Kings Creek on the northwest. The long axis of the peninsula, which is oriented approximately 45° east of north, is  $\approx 448$  m ( $\approx 1,470$  ft) long x  $\approx 107$  m ( $\approx 350$  ft) wide. The maximum altitude of the land surface is  $\approx 4.6$  m ( $\approx 15$  ft) above mean sea level (Nemath, 1989); the average elevation is  $\approx 3$  m ( $\approx 10$  ft) above mean sea level (McGinnis et al., 1994).

#### 3.2 Historical Use

Beach Point has been used for a number of activities which may have contributed to the contamination of the soils and groundwater as well as Kings Creek and Bush River (Nemath, 1989). The major operations include 1) mobile and fixed-based clothing impregnating plant activities during World War II; 2) liquid rocket fuel testing from the early 1960s through the 1970s; and 3) pyrotechnic testing with grenades and pots filled with obscurant smoke from the post-World War II period to about 1970.

As discussed in Nemath (1989), the clothing impregnating process involved the use of several solvents which included 1,1,2,2-tetrachlorethane, N,N'-dichloro-bis(2,4,6-trichlorophenyl)urea, chlorobenzene, and other solvents. Losses of the hazardous materials may have occurred through volatilization, spillage, or leakage, as well as direct discharge to Kings Creek and/or the Bush River. Historical photographs indicate that the materials may have also been discharged to small pits located near the clothing impregnating plants. Various fuels, oxidizers, and fire suppressants were used in the liquid rocket fuel testing programs. Wastewater from the tests was either discharged directly to the Bush River and/or Kings Creek, or may have been allowed to run off onto the ground surface. The primary materials used in the pyrotechnic testing were white obscurant smokes and fog oil. Materials associated with pyrotechnic testing often include aluminum, magnesium, zinc, lead, and titanium, as well as petroleum compounds, hexachloroethane, and other organic compounds (JEG, 1993).

#### 3.3 Groundwater Contamination

Because of possible groundwater contamination from historical activities at Beach Point, USGS began placing observation wells at Beach Point in 1986 as part of a larger

study of the Canal Creek area (Lorah and Vroblesky, 1989). Five wells, located in three clusters, were originally drilled in the surficial aquifer (see Section 3.4) at Beach Point during 1986 in the proximity of the former clothing impregnating plants. A sixth well (CC-33B.1) was drilled in 1988. The three clusters contain the following wells. Cluster 32 consists of wells CC-32A and CC-32B which have screened depths below land surface of 3.2-4.7 and 6.4-7.9 m (10.5-15.5 and 21-26 ft), respectively. Wells 33A, 33B, and 33B.1 in cluster 33 have screened depths of 3.4-4.9, 18.9-20.4, and 12.5-14.0 m (11-16, 62-67, and 41-46 ft), respectively. Well 34A, with a screen interval of 4.3-5.8 m (14-19 ft), is the only well in cluster 34. Of the six monitoring wells at Beach Point in the surficial aquifer, four are shallow with screen depths that range from 3.2-6.9 m (10.5-26 ft), one well (CC-33B.1) is intermediate with a screen depth of 12.5-14.0 m (41-46 ft), and one well (CC-33) is deep with a screen depth of 18.9-20.4 m (62-67 ft).

Chemical monitoring (inorganic and organic constituents) by USGS during 1988 confirmed that hazardous chemicals from prior activities were present in the groundwater (Lorah and Vroblesky, 1989 and Lorah and Clark, 1992). Several inorganic constituents exceeded Federal drinking water standards; the highest concentrations were found in the deep well (CC-33B). Several heavy metals were also found in the wells. The highest concentrations were generally found in wells CC-33B and CC-33B.1; the concentrations of heavy metals in wells CC-33B and CC-33B.1 were similar. A number of volatile chlorinated aliphatic compounds were found in the groundwater at Beach Point. With the exception of chloroform in well CC-32A and methylene chloride in wells CC-33A and CC-33B.1, the highest concentrations of the volatile organics were found in the deep well CC-33B. Wells CC-33A and CC-33B only were studied at Beach Point during 1989. The concentrations of heavy metals and volatile organics were all higher in the deep well (CC-33B) than in the shallow well (CC-33A).

The chlorinated aliphatic organics that occur at the lower depths of the aquifer may be present as a residual denser-than-water nonaqueous phase liquid (DNAPL) (Cohen and Mercer, 1993; Knox et al., 1993). McGinnis et al. (1994) recently found that the surficial aquifer at Beach Point is a relatively low-resistivity lens pierced by high resistivity "plumes" that may indicate the presence of DNAPLs. Additional chemical data are needed from the high resistivity plumes in areas other than well CC-33B to confirm the presence of DNAPLs.

### 3.4 Geology

The geology of the Canal Creek area has been described by USGS (Oliveros and Vroblesky, 1989). JEG (1993) has recently summarized the geology of the Beach Point study site. Briefly,

the Aberdeen Proving Ground-Edgewood Area is underlain by coastal plain sediments consisting of unconsolidated clay, silt, and sand layers with occasional gravel lenses. At Beach Point the surficial sediments consist of a clayed soil to a depth of  $\approx 1.2$  m (4 ft), underlain by  $\approx 18.2$  m ( $\approx 60$  ft) of fine- to medium-grained, well-sorted sand, interfingering with thin lenses of clay and silty sand and sometimes containing coarse sand and gravel layers (Oliveros and Vroblesky, 1989). The surficial unit, which appears to be part of the Potomac Group, is underlain by a clay layer called the upper confining unit. According to JEG (1993), the upper confining unit, which has a thickness of  $\approx 27$  m (88 ft), does not appear to have been penetrated at Beach Point. Thus, it is unlikely that the Canal Creek Aquifer below the upper confining unit has been contaminated by activities at Beach Point. The Beach Point surficial sediments and clay upper confining unit appear to dip gently ( $\approx 15$  m/mile; 50 ft/mile) to the southeast.

### 3.5 Groundwater Hydrology

Groundwater at Beach Point is encountered at shallow depths from less than 4 m (13 ft) to about 4.9 m (16 ft) below ground surface in most areas under unconfined conditions (JEG, 1993). The surficial aquifer at Beach Point appears to be an isolated part of the surficial aquifer identified throughout the Canal Creek area by Oliveros and Vroblesky (1989). The surficial aquifer is hydraulically interconnected to Kings Creek, Bush River, and associated wetlands. Limited studies by USGS in 1988 and 1989 showed that the surficial aquifer was tidally influenced (Oliveros and Vroblesky, 1989). Quarterly groundwater elevation monitoring by USGS in wells installed at Beach Point showed that relatively constant water levels (within tidal variations) occurred over the year, with little seasonal variation (Oliveros and Vroblesky, 1989). According to JEG (1993), this indicates that the surficial aquifer at Beach Point is more strongly influenced by tidal conditions than by recharge from infiltrating precipitation.

A recent study of the six monitoring wells described in Section 3.3 above for Beach Point confirmed that the groundwater is tidally influenced (K-V Associates, Inc., 1994). The study showed that all wells exhibited tidal influence. There were varying amounts of tidal influence including both horizontal and vertical components in the groundwater. Wells with shallower screens (CC-32A, CC-33A, and CC-34A) exhibited smaller fluctuations relative to deeper wells with a more permeable stratum (CC-32B, CC-33B, and CC-33B.1). Groundwater flow directions and rates were also substantially influenced by tidal stage. The predominant direction of horizontal flow was to the northeast.

### 3.6 Surface Water Hydrology

Kings Creek, which drains  $\approx 324$  ha ( $\approx 800$  acres), is essentially a tidal estuary associated with the Bush River. As discussed by JEG (1993), flow from the creek appears to occur mainly as a result of tidal flushing. Net advective flow resulting from the stream gradient appears to be minimal. Drainage into the main body of the creek is through numerous subsidiary streams and wetlands. The tidal range for the creek is typically  $<0.3$  m (1 ft). Salinity generally varies from approximately 1 to 3 parts per thousand (ppt). The depth of the creek is  $<3$  m (10 ft).

The Bush River, a tributary estuary of the Chesapeake Bay, has a tidal range of 0.15 to 0.46 m (0.5 to 1.5 ft) at Beach Point (JEG, 1993). The river is approximately 1.6 km (0.87 nautical mile) wide at Beach Point and is generally  $<1.8$  m (6 ft) deep except in the shipping channel, where the depth is about 6.1 m (20 ft) (JEG, 1993). The salinity of the river in the vicinity of Beach Point can vary considerably on a seasonal basis; the average is  $\approx 3$  ppt (Pritchard, 1976).

As discussed by Carter (1976), the Bush River is  $\approx 15.7$  km (8.5 nautical miles) long measured along its axis from mouth to head. The depth increases generally from head to mouth with the maximum depth of 9.8 m (32 ft) near Briery Point; the mean depth is  $\approx 1.8$  m (6 ft). At its widest point, the river is  $\approx 3.7$  km (2 nautical miles) wide. The tide in the Bush River is semidiurnal with a mean range of 0.4 m (1.4 ft) reported for Pond Point. This tidal range results in an intertidal volume of  $\approx 1.2 \times 10^7$  m<sup>3</sup> ( $42.9 \times 10^7$  ft<sup>3</sup>). This is about 20% of the volume below mean tide level. At the time of maximum tidal velocity at the entrance, the discharge through the mouth of the river is  $\approx 850$  m<sup>3</sup> sec<sup>-1</sup> ( $30 \times 10^3$  ft<sup>3</sup> sec<sup>-1</sup>). The major tributaries to the river include Otter Point Creek, Lauderick Creek, and Kings Creek. The drainage of the Bush River is  $\approx 29.5 \times 10^3$  ha (113.9 miles<sup>2</sup>), resulting in a mean annual runoff of the order of 3.68 m<sup>3</sup> sec<sup>-1</sup> (130 ft<sup>3</sup> sec<sup>-1</sup>) (Carter, 1976). Thus, waters in the Bush are derived mainly from the adjacent Chesapeake Bay.

## SECTION 4

### MATERIALS AND METHODS

#### 4.1 Biomonitoring Evaluation

Groundwater was withdrawn from well CC-33B (Hartford County Permit No. HA-81-4049) which is the most highly contaminated well at Beach Point (Section 3.3). The well is 21.3 m deep (70 feet) and has a screened interval of 18.0-20.4 m (62-67 ft). The well pump intake was located at 19.8 m (65 feet). Groundwater was pumped continuously from the well at a rate of  $\approx 7.5$  L/min (2 gal/min).

Several components of the biomonitoring study were conducted on-site (see below) in an aquatic biomonitoring trailer with bioassay capabilities similar to a USABRDL trailer described by Herriott and Burton (1992). Groundwater and dilution water (APG-EA potable water) were supplied to the trailer via polyethylene pipe. The dilution water was charcoal filtered and aerated before use. Excess groundwater and diluent water from the trailer were collected, treated via charcoal, and pumped to the APG-EA Wastewater Treatment Plant for further treatment.

An array of biomonitoring systems were evaluated during the 9-month study. The biomonitoring systems included a number of endpoints. A summary of the biomonitoring tests conducted is given in Table 1. The pH of the groundwater from well CC-33B was 4 ( $\pm 0.1$ ); thus, many of the assays were conducted at both pH 4 and pH 7. The toxicity at pH 7 was studied so that the data could ultimately be used in a hazard assessment of the groundwater as it enters the Bush River which generally has a pH in the low neutral range.

The experimental procedures and frequency of each assay are described in detail below. The following is a brief description of the tier of biomonitoring systems employed in the evaluation. Acute toxicity of the groundwater was evaluated three times each week using the 5- and 15-min Microtox® assay which uses microbial (Photobacterium phosphoreum) bioluminescent activity. In addition to providing rapid toxicity data, the test was also conducted to monitor the toxicity of the groundwater over time. A rapid 24-h rotifer (Branchiopus rubens) test was conducted to determine acute toxicity. The rotifer bioassay was conducted four times on a bimonthly basis during the course of the study at a pH of 4 and 7. Acute toxicity data were also obtained for the algal, invertebrate, and fish used in the short-term toxicity tests described in Section 4.1.2 below. An acute toxicity test was also conducted with the Japanese medaka (Oryzias latipes).

TABLE 1. SUMMARY OF THE BIOMONITORING TESTS CONDUCTED

Test and/or Species	Type of Test	Test No.	Test Periods	Comments
Microtox® (bacterium)	5- and 15-min EC50	N/A	03/24/93 - 12/06/93	Grab and/or composite sample <sup>a</sup>
Rotifer	24-h LC50	1 2 3 4	04/10/93 - 04/12/93 06/02/93 - 06/04/93 08/24/93 - 08/26/93 12/01/93 - 12/03/93	Grab and composite sample <sup>b</sup>
Green alga	96-h EC50; 96-h Growth	1 2 3 4	04/10/93 - 04/14/93 06/03/93 - 06/07/93 08/24/93 - 08/28/93 12/01/93 - 12/05/93	Grab and composite sample <sup>b</sup>
Cladoceran	48-h LC50; 7-d Survival and reproduction	1 2 3 4	04/07/93 - 04/14/93 06/01/93 - 06/08/93 08/24/93 - 08/31/93 11/30/93 - 12/07/93	Grab and composite sample <sup>c</sup>
Fathead minnow	96-h LC50; 7-d Survival and growth	1 2 3 4	04/07/93 - 04/14/93 06/02/93 - 06/09/93 08/24/93 - 08/31/93 11/30/93 - 12/07/93	Grab and composite sample <sup>c</sup>
Japanese medaka	96-h LC50	N/A	11/30/93 - 12/04/93	Grab and composite sample <sup>c</sup>
Genotoxicity (bacterium)	Ames assay	1 2 3 4	04/14/93 06/02/93 08/23/93 11/30/93	Grab and/or composite sample <sup>d,e</sup>



TABLE 1. (CONTINUED)

Test and/or Species	Type of Test	Test No.	Test Periods	Comments
Genotoxicity (Chinese hamster ovary cells)	SCE assay	N/A N/A N/A N/A	06/02/93 07/19/93 08/23/93 11/30/93	Grab and/or composite sample <sup>f</sup>
Developmental toxicity (African clawed frog)	4-d FETAX	1 2 3 4	04/10/93 - 04/14/93 06/03/93 - 06/07/93 08/26/93 - 08/30/93 12/03/93 - 12/07/93	Grab and composite sample <sup>c</sup>
Chronic histopathology and growth (Japanese medaka)	6 and 9 Months	N/A	02/25/93 - 11/29/93	Flow-through exposure conducted in biomonitoring lab
Comprehensive chemical analyses	N/A	1 2 3 4	04/14/93 06/02/93 08/23/93 11/30/93	Grab and composite sample <sup>g</sup>
Munitions analyses	N/A	1 2 3 4	04/14/93 06/02/93 09/30/93 11/29/93	Grab sample of 100% groundwater
Routine water quality analyses	N/A	N/A	Daily/weekly	Grab sample <sup>h</sup>

<sup>a</sup> Grab sample of 100% groundwater and composite grab samples of 10 and 1% groundwater by volume taken 3 times a week; composite grab sample of diluent water taken once a week.

TABLE 1. (CONTINUED)

Test and/or Species	Type of Test	Test No.	Test Periods	Comments
<sup>b</sup>	Grab sample of 100% groundwater; composite grab sample of diluent water.			
<sup>c</sup>	Grab sample of 100% groundwater and composite grab sample of diluent water renewed every 24 h.			
<sup>d</sup>	Composite grab samples of 10 and 1% groundwater by volume and diluent water taken for analysis on 04/14/93 and 06/02/93.			
<sup>e</sup>	Grab sample of 100% groundwater and composite grab samples of 10% groundwater by volume and diluent water taken for analysis on 08/23/93 and 11/30/93.			
<sup>f</sup>	Samples taken for analyses were as follows: composite grab sample of 10% groundwater by volume on 06/02/93, grab sample of 100% groundwater on 07/19/93 and 11/30/93, and composite grab sample of diluent water on 08/23/93.			
<sup>g</sup>	Grab sample of 100% groundwater and composite grab samples of 10 and 1% groundwater by volume and diluent water taken for analysis during each test period listed.			
<sup>h</sup>	Grab samples taken from chronic histopathology tanks as described in Section 4.1.6.2.			

The following 4- to 7-d short-term toxicity tests, which were used to estimate chronic toxicity, were performed on a bimonthly basis: 96-h algal (Selenastrum capricornutum) growth test; 7-d cladoceran (Ceriodaphnia dubia) survival and growth test; and 7-d fathead minnow (Pimephales promelas) survival and growth test. Four bimonthly tests were conducted with each species at pH 4 and pH 7. In addition to the short-term methods used to estimate chronic toxicity, growth data at 6 and 9 months from the chronic Japanese medaka histopathology test described below were also used as chronic toxicity endpoints.

Gene mutation potential was determined using the Ames Salmonella/mammalian-microsome reverse assay. Primary DNA damage was evaluated by the sister chromatid exchange (SCE) assay. Developmental toxicity was determined by the 96-h frog embryo teratogenesis assay-Xenopus (FETAX) using the African clawed frog, Xenopus laevis. Genotoxicity and developmental toxicity assays were conducted at bimonthly intervals during the same periods as the above acute and short-term chronic tests were conducted. Chronic histopathological changes were evaluated using the Japanese medaka as the experimental model. Both unexposed and fry exposed to diethylnitrosamine (DEN) were exposed continuously under flow-through test conditions for 6- and 9-month exposure periods.

Comprehensive chemical analyses of the raw groundwater, test dilutions in the chronic histopathology assay, and diluent water were performed four times at bimonthly intervals. The chemical analyses were conducted during the same periods that the above bimonthly assays were conducted. Routine water quality analyses were also conducted at various frequencies on a weekly basis.

#### 4.1.1 Acute Toxicity Tests

##### 4.1.1.1 Microtox®

The Microtox® test (Microbics Corp., Carlsbad, CA) is a rapid acute toxicity test that may be completed in less than one hour. The test is based on the reduction in bioluminescence of the marine bacterium P. phosphoreum when exposed to a sample of unknown toxicity. The degree of light reduction, an indication of metabolic inhibition in the test preparation, indicates the degree of toxicity of the sample. The Microtox® test procedures followed were those outlined in Herriott and Burton (1992) which were derived from Microtox®'s operating manual (Microtox®, 1988). A Microtox® Model 500 Analyzer with PC version 6.3 software was used for both a 5-min and 15-min test on all samples.

Microtox® assays were initiated on April 2, 1993. The assays were conducted on-site three times a week until the biomonitoring study was completed on December 6, 1993. Both 5- and 15-min assays were conducted on 100, 10, and 1% groundwater

by volume samples as well as APG-EA diluent water. The 10 and 1% groundwater by volume samples were taken from the chronic histopathology study tanks as described below in Section 4.1.5. A 5- and 15-min assay was conducted once each week on 100% groundwater adjusted to pH 7 with 10 N NaOH.

#### 4.1.1.2 Rotifer

The 24-h freshwater rotifer Toxkit™ screening test (Bio-Response Systems, Halifax, Nova Scotia) was used to determine the potential toxicity of the groundwater at pH 4 and 7 (groundwater buffered with 10 N NaOH). pH-adjusted aliquots of the same groundwater used for the short-term chronic toxicity tests were used for the rotifer assays (see Section 4.1.2). The test utilized newly hatched rotifers (*B. rubens*) <4 h old. The rotifers used in the tests were hatched from cysts supplied in the Rotifer ToxKit™. Rotifer ToxKit™ synthetic medium was used to hatch the cysts, rear the organisms before testing, and as diluent media for the tests. The static tests were conducted in glass Petri dishes containing 10 mL of test solution.

The groundwater, which was used within 6 h from the time of collection for the rotifer bioassays, was held in glass containers at 4°C until used in the tests. A geometric series of five groundwater concentrations (plus controls) was used. Three replicates of 10 organisms each were used at each test concentration. All tests were conducted at  $25 \pm 0.5^\circ\text{C}$ . Routine water quality (alkalinity, conductivity, DO, hardness, pH, and temperature) was measured at the beginning and end of each test. The methods used for the chemical analyses are given in Section 4.1.6.2. All tests were conducted under a 16-h light:8-h dark photoperiod (fluorescent lights at 60-85 foot candles).

#### 4.1.1.3 Green Alga, Cladoceran, Fathead Minnow, and Japanese Medaka

Acute toxicity values were calculated where possible at pH 4 and 7 for the green alga, cladoceran, and fathead minnow from the data obtained during the short-term chronic tests described in Section 4.1.2. With regard to the green alga, EPA's Office of Research and Development considers the 96-h algal test for growth to be a short-term chronic test for determining the toxicity of effluents (Horning and Weber, 1985; Weber et al., 1989) as do other investigators for evaluating single chemicals (for ex., see Hughes et al., 1988 and Suter, 1993). EPA's Toxic Substance Control Act office considers the 96-h test to be an acute test (U.S. EPA, 1985a and 1986a). Because we used the short-term chronic method (Section 4.1.2.1), we analyzed the data as chronic data; however, we also analyzed and reported the results as 96-h acute data so that acute:chronic ratios could be calculated for use in the hazard assessment (Section 4.2).

Forty-eight-h LC50s and 96-h LC50s were determined where possible for the cladoceran and fathead minnow, respectively. One 96-h acute toxicity test was conducted with the Japanese medaka using the procedure of Weber (1991). The age of the Japanese medaka used in the test was 22 d old at the start of the exposure; the test procedure recommends fish between the ages of 1-14 d old be used.

#### 4.1.2 Short-term Chronic Toxicity Tests

The specific test methods for the short-term chronic tests are given below. Deviations from the test methods are discussed where appropriate. A geometric series of five groundwater concentrations (plus controls) was used in most tests. The groundwater samples used in all tests were obtained daily and used within 6 h at each 24-h renewal (see below). All groundwater samples were transported in glass containers on ice and held at 4°C until used for the tests. Each groundwater sample was split into two aliquots. One aliquot was maintained at pH 4 and the second buffered to pH 7 (10 N NaOH). All bimonthly short-term chronic bioassays were conducted at pH 4 and 7. The same pH-adjusted aliquots were also used for the rotifer bioassays (Section 4.1.1.2) and FETAX assays (4.1.4). The bioassays were conducted at the University of Maryland Wye Research and Education Center (UMD/WREC) Aquatic Toxicology Laboratory.

##### 4.1.2.1 Green Alga

The short-term chronic toxicity of the groundwater to the green alga (S. capricornutum) at pH 4 and 7 (10 N NaOH) was determined four times by the EPA procedures given in Weber et al. (1989). A starter culture of S. capricornutum was obtained from the culture collection at the University of North Texas, Denton, TX. Stock algal cultures were reared in 2.5 L Pyrex culture flasks containing 1 L of sterilized double strength "AAP" algal assay medium, with sufficient P added to achieve a 20:1 N:P ratio as described in Miller et al. (1978). Cultures were maintained in a constant temperature incubator under constant cool-white fluorescent lights ( $\approx 300$  foot candles) at a temperature of  $25 \pm 0.2^\circ\text{C}$  on a shaker table oscillating at 100 rpm ( $\pm 10\%$ ). Log growth cells were used to start all tests.

Algal test solutions were prepared by dilution of the groundwater with filtered sterilized assay media. Test solutions (100 mL total volume) were dispensed into 250 mL Delong flasks and inoculated with S. capricornutum cells in log growth to achieve a density of  $\approx 1 \times 10^4$  cells/mL. Triplicates were prepared for each treatment. The flasks were placed on a shaker table in an incubator set at the culturing conditions described above. Growth measurements (cell density) were made from all replicates in each treatment at 0, 24, 48, 72, and 96 h. Algal

cell density was determined from a 1 mL sample with a Model ZBI Coulter Counter (Coulter Electronics, Inc., Hialeah, FL). The instrument was calibrated with each use via hemocytometer counts. Test solutions were not renewed during the 96-h studies.

#### 4.1.2.2 Cladoceran

The chronic toxicity of the groundwater at pH 4 and 7 to C. dubia was determined four times by the EPA static renewal method (solutions renewed daily) given in Weber et al. (1989). The cladoceran was cultured at  $25 \pm 1^\circ\text{C}$  in 600 mL glass beakers filled with 400 mL of 20% Perrier:80% reverse osmosis water amended with selenium ( $2 \mu\text{g Se/L}$  as  $\text{Na}_2\text{SeO}_3$ ) as recommended by Winner (1989). The diet consisted of a mixture of Cerophyl® (Cerophyl Laboratories, Inc., Kansas City, MO) and the green alga, S. capricornutum, added to the cladoceran culture to achieve final concentrations of  $120 \mu\text{g Cerophyl}^\circ/\text{mL}$  and  $6.7 \times 10^5$  S. capricornutum cells/mL. Starter cultures of C. dubia were obtained from the Center for Lake Superior Environmental Studies, University of Wisconsin - Superior.

All neonates used in the 7-d survival and reproduction tests were produced by cladocerans in culture that had released at least three broods. The initial age of the neonates in each test was <12 h old. The tests were conducted in 50 mL glass beakers containing 30 mL of test solution. All tests were conducted in an environmental chamber at  $25 \pm 1^\circ\text{C}$  under a 16-h light:8-h dark photoperiod (fluorescent lights; 60-85 foot candles at the surface of the culture vessels). All test organisms were fed daily as described above at each 24-h renewal. Routine water quality was taken at the beginning and end of each 24-h renewal. The methods used for the chemical analyses are discussed in Section 4.1.6.2.

#### 4.1.2.3 Fathead Minnow

The toxicity of the groundwater at pH 4 and 7 to fathead minnows (P. promelas) was determined four times by the EPA static renewal method (solutions renewed daily) given in Weber et al. (1989). All larvae used in the 7-d survival and growth tests were <24 h old at the start of the test. The tests were conducted in 600 mL glass beakers containing 400 mL of test solution. The dilution water was a 20% Perrier:80% reverse osmosis water. All test organisms were fed brine shrimp (Artemia sp.) nauplii <24 h old daily at each 24-h renewal. All tests were conducted at  $25 \pm 1^\circ\text{C}$  under a 16-h light:8-h dark photoperiod (fluorescent lights; 60-85 foot candles). Routine water chemistry was performed at the beginning and end of each renewal. Dry weight was determined by drying at  $100^\circ\text{C}$  for a minimum of 12 h.

Fathead minnow larvae were obtained from the UMD/WREC culture maintained at  $25 \pm 1^\circ\text{C}$  in UMD/WREC non-chlorinated well water (mean dissolved oxygen = 8.2; pH = 7.8; conductivity = 161  $\mu\text{S}/\text{cm}$ ; alkalinity = 53 mg/L as  $\text{CaCO}_3$ ; hardness = 52 mg/L as  $\text{CaCO}_3$ ). The UMD/WREC culture procedures were similar to those recommended by Peltier and Weber (1985). The UMD/WREC culture was initiated with mature fathead minnows obtained from the U.S. EPA Environmental Monitoring and Support Laboratory - Cincinnati, Ohio.

Spawning fish were cultured in fiberglass tanks (2.4 x 0.8 x 0.5 m) containing 0.2 m UMD/WREC well water held at  $25 \pm 1^\circ\text{C}$ . The spawning adults were fed a diet of frozen brine shrimp (*Artemia* sp.; Argent Chem. Lab., Redmond, WA) and TetraMin® Staple Food (Ramfab Aquarium Products Co., Oak Ridge, TN) twice daily. Excess food was removed daily. Four sets of spawning fathead minnows were maintained in the culture tanks at a ratio of 1 male:4 females. Replacement spawners were rotated at approximately 3-month intervals. Fathead minnow embryos were collected on spawning substrates (10 cm I.D. x 20 cm long PVC pipe sections cut longitudinally in equal portions) and transferred to 19 L aquaria at  $25 \pm 1^\circ\text{C}$  in UMD/WREC well water for hatching. All stages of the fish were reared under a 16-h light:8-h dark photoperiod (fluorescent lights; 60-85 foot candles).

#### 4.1.3 Genotoxicity Tests

##### 4.1.3.1 Gene Mutation Assay

The Ames assay was used to predict chemical mutagenic activity which in turn may serve as a carcinogen prescreen test (Ames et al., 1973). *Salmonella typhimurium*/mammalian-microsome reverse mutation assays were conducted four times on the groundwater and APG diluent water samples described below. The assays were conducted on both unconcentrated and concentrated (10X via XAD-2 resin extracts) samples of the groundwater and diluent water. The Ames mutagenicity assays were conducted by Hazleton Washington, Inc., Vienna, VA.

Grab samples of groundwater were collected in polypropylene containers as follows. Raw groundwater was taken directly from the well fed line to the biomonitoring laboratory. Groundwater samples of 10 and 1% groundwater by volume were taken as composite samples from the chronic histopathology fish tanks described in Section 4.1.5. Grab samples of APG-EA diluent water were taken from a large polypropylene tank with a 99% particle replacement time of  $\approx 12$  h. Thirty-one liters (1 L for an unconcentrated sample and 30 L for a 10X sample) of each material were siphoned into Nalgene polycarbonate carboys, packed in ice, and transported to Hazleton Washington, Inc. in insulated containers. The unconcentrated samples were analyzed by Hazleton

Washington, Inc. Protocol No. HLA Protocol 401W, Edition 17. The concentrated (10X) samples were analyzed by Protocol No. HLA Protocol 401X, Edition 18.

Detailed experimental procedures for the unconcentrated and 10X tests are given in the protocols listed above. Briefly, the mutagenicity assays evaluated the groundwater and diluent water samples for their ability to induce reverse mutations at the histidine locus in the genome of specific S. typhimurium tester strains both in the presence and absence of an exogenous metabolic activation system of mammalian microsomal enzymes derived from Aroclor 1254-induced rat liver. The tester strains used in the assays were TA98 and TA100. The assays were conducted using two plates per dose level in the presence of microsomal enzymes. Six dose levels of the groundwater and diluent water samples were tested in both the presence and absence of S9 along with appropriate vehicle controls (three plates per dose), negative controls, and positive controls. Resin controls were also run for the 10X samples. The doses tested in the 10X assays varied based on the amount of extractable organics recovered from the test material.

#### 4.1.3.2 Sister Chromatid Exchange Assay

The sister chromatid exchange (SCE) assay was used as a test for possible genetic damage induced by chemical mutagens (Perry and Evans, 1975). We are aware that many mutagens are active in SCE assays, yet, it is still incompletely understood how DNA damage or perturbations of DNA synthesis give rise to SCE (Hoffman, 1991). The assay was performed once on concentrated samples ( $\approx 50,000X$ ) of 100% raw groundwater, 10% groundwater by volume, and APG-EA diluent water. One assay was also conducted on unconcentrated 100% groundwater. The SCE assays were conducted by Hazleton Washington, Inc., Vienna, VA.

Grab samples of groundwater were collected in polypropylene containers as follows. The 100% groundwater samples were taken directly from the well fed line to the biomonitoring laboratory. The 10% groundwater by volume sample was taken as a composite sample from the chronic histopathology fish tanks described below. A grab sample of APG-EA diluent water was taken from a large polypropylene tank with a 99% particle replacement time of  $\approx 12$  h. Thirty liters were siphoned into Nalgene polycarbonate carboys, packed in ice, and transported to Hazleton Washington, Inc. in insulated containers. The samples were assayed by Hazleton Washington, Inc. using their Genetics Protocol No. 438, Edition 15.

The experimental procedures for the SCE assay are given in the protocol listed above. Briefly, 30 L of each sample were concentrated in DMSO to a final volume of 6 mL ( $\approx 50,000X$ ) by rotoevaporation. The unconcentrated 100% groundwater sample was



not concentrated by rotoevaporation. The extract was evaluated for its ability to induce sister chromatid exchanges (determined at metaphase) in Chinese hamster ovary (CHO) cells in the presence and absence of an exogenous metabolic activation system of mammalian microsomal enzymes derived from Aroclor 1254-induced rat liver. The SCE assays were conducted by exposing cultured cells to the test extract, growing the cells with the thymidine analog of 5-bromo-2'-deoxyuridine for about two cell cycles, and making chromosome preparations that were Giemsa-stained for SCE. The doses tested were selected based on the amount of extractable organics recovered from the test article. Single cultures of CHO cells were incubated with five concentrations of the extract with and without metabolic activation. Sister chromatid exchange frequencies were analyzed in the cultures treated with the two highest doses with second generation cells and from solvent and positive control cultures.

#### 4.1.4 Developmental Toxicity Test

Four bimonthly developmental toxicity tests were conducted at pH 4 and 7 using the frog embryo teratogenesis assay - Xenopus (FETAX). The assay is a 96-h quantitative developmental assay used to screen for developmental toxicants in aquatic media. The assays were conducted using the static renewal (solutions renewed every 24 h) test method Designation E 1439-91 of the American Society for Testing and Materials (ASTM, 1992a). Embryo lethality and malformations were determined; growth retardation was not evaluated. The identification and interpretation of malformations in the embryos at 96 h were made via the atlas of Bantle et al. (1991). Aliquots of the same groundwater used for the rotifer, algal, and short-term chronic toxicity biomonitoring tests were used for the FETAX assays (Section 4.1.2).

Embryos between normal stage 8 blastulae and normal stage 11 gastrulae were obtained from X. laevis breeding colonies at the UMD/WREC as described below. The embryos were de-jellied in a 2% L-cysteine solution (2 g of L-cysteine per 98 mL of FETAX solution). Once de-jellied, the embryos were rinsed and re-suspended in FETAX solution (ASTM, 1992a). The embryos were tested in glass petri dishes containing 10 mL of solution. Two replicates of 25 embryos/replicate were used for each test treatment. As required by the study protocol, four replicates of 25 embryos/replicate were used for the control treatment. The tests were conducted at  $24 \pm 0.2^\circ\text{C}$  under a 16-h light: 8-h dark photoperiod (fluorescent lights;  $\approx 75$  foot candles at the surface of the test medium) in a constant temperature environmental chamber.

The UMD/WREC X. laevis adult colony was maintained in flow-through ( $\approx 4$  replacement volumes per day) circular polyethylene aquaria (0.91 m I.D. x 0.36 m high) with a water depth of 10 cm. Each aquarium contained a maximum of 10 adults. UMD/WREC non-

chlorinated deep well water (water quality given in Section 4.1.2.3 ) held at  $23.5 \pm 0.5$  °C served as the culture medium. All frogs were fed every 5-6 d with commercial beef liver supplemented with liquid vitamins (PolyViSol; Mead-Johnson Nutritionals, Evansville, IN). The colony was held under a photoperiod of 16h light:8 h dark. Mating pairs were bred in the dark in  $23.5 \pm 0.5$  °C UMD/WREC non-chlorinated water at  $\approx 70$  d intervals by injecting 400 and 800 I.U. of human chorionic gonadotropin (HCG) in the dorsal lymph sac of the males and females, respectively. Amplexus occurred 4-6 h after injecting HCG; egg deposition occurred 9-12 hours following HCG injection. The original breeding stock was obtained from Xenopus I (Ann Arbor, MI).

#### 4.1.5 Chronic Histopathology and Growth Test

Chronic histopathologic changes were evaluated using the Japanese medaka (*O. latipes*) as the experimental model. The Japanese medaka is a sensitive laboratory model for screening environmental pollutants which may induce histopathological changes and neoplasms (for ex., see Hawkins et al., 1988; Klaunig et al., 1984; Metcalfe, 1989). Both unexposed and fry exposed to diethylnitrosamine (DEN) were exposed continually under flow-through test conditions for a 9-month period. A subset of organisms was taken after 6 months of exposure for morphometric measurements and histopathological evaluation. The USABRDL test designation was Protocol No. 401-001R.

The fish were exposed to one of three treatments: 10% groundwater by volume, 1% groundwater by volume, or APG-EA diluent water (control). A 100% groundwater treatment could not be used because the pH of the groundwater was 4 ( $\pm 0.1$ ) which would have caused excessive mortality over the 9-month exposure period. Consideration was given to buffering the 100% groundwater to pH 7 and conducting the 100% treatment at pH 7. However, a preliminary evaluation of the buffered groundwater at pH 7 showed that excessive precipitation of metals occurred. Thus, 100% groundwater was not buffered to pH 7 and used as an experimental treatment.

The flow-through test solutions were delivered by a solenoid-activated proportional dilutor system which was constructed primarily of glass and stainless steel; some silicon tubing was also used. The test concentrations were delivered to twelve 19 L (5 gal) glass aquaria (4 aquaria at 10% groundwater by volume; 4 at 1% groundwater by volume; and 4 control aquaria); each aquarium contained a volume of  $\approx 16$  L (4.25 gal). All aquaria were held at  $25 \pm 1$  °C in a constant temperature water bath. The dilutor was calibrated to complete one full cycle every 2.5 to 3.5 min. During a cycle, tanks 1-4 each received  $300 \pm 15$  mL of APG-EA diluent water, tanks 5-8 each received  $300 \pm 15$  mL of 10% groundwater by volume, and tanks 9-12 each

received  $300 \pm 15$  mL of 1% groundwater by volume.

Both unexposed fry and fry exposed to DEN, were reared off-site at USABRDL until 17 d old. The DEN-initiated fish were exposed to 10 mg/L DEN for 48 h when the organisms were 12 to 14-d old. Prior to the start of the exposure to groundwater, the 17-d old fish were randomized into 6 groups of 60 fish/group for both the unexposed and DEN-initiated groups. The fish were suspended in 12 1-L mesh-bottom glass beakers in the appropriate flow-through test aquaria in the biomonitoring laboratory. The fish were held in the beakers for one week after which they were released into the aquaria.

Japanese medaka, 17-22 d old, were fed microworms two feedings per day and live brine shrimp (*Artemia* sp.) (<24 h old) two feedings per day (30 brine shrimp/fish). Pre-adult fish, 23-30 d old, were fed Tetramin® flake food two feedings per day and live brine shrimp <24 h old (one feeding per day; 40 brine shrimp per fish). Adult fish, >30 d old, were fed Tetramin® flake food (three feedings per day on Tuesday and Thursday and two feedings per day on the remaining days) and live brine shrimp (one feeding per day on Monday, Wednesday, and Friday). The ration was adjusted as the size of the fish increased. Tanks were cleaned on an as needed basis (usually 1-2 times a week) by scrubbing algae from the sides of the tanks, allowing the debris to settle, and then siphoning. Tetramin® was fed ad libitum for 15-30 min during each feeding.

The number of test organisms alive in each tank were monitored and recorded daily. Moribund fish were euthanized and fixed in Bouin's solution for subsequent histological observation. The dilutor cycle time was calculated and recorded daily. The volume of groundwater and diluent water delivered to the aquaria were checked weekly. When necessary, cycle time and/or volume distributions were adjusted. The dilutor was occasionally shutdown (for no more than one hour) and cleaned on an as needed basis. Daily water quality (DO, pH, and temperature) was determined in all aquaria. Additional water quality tests (alkalinity, hardness, conductivity, total residual chlorine, free available chlorine, and total ammonia-nitrogen) were performed once a week in all aquaria (Section 4.1.6.2). A 16-h light:8-h dark photoperiod (fluorescent lights at 70-100 foot candles) was maintained throughout the study. Unionized ammonia-nitrogen was determined by the method of Thurston et al. (1979). Comprehensive chemical analyses were performed four times at bimonthly intervals as discussed in Section 4.1.6.1 on 100, 10, and 1% groundwater by volume and APG-EA diluent water during the test periods shown in Table 1.

On day 180, 20 Japanese medaka in each tank were removed and taken back to USABRDL for fixation (Bouin's solution) and subsequent histological observation. Wet weight and standard

length measurements were taken on all fish. The morphometric data were taken to assess the effects of a chronic 6-month exposure to the contaminated groundwater as well as the general health of the fish. On day 278, when the exposure was completed, the remaining Japanese medaka were also taken back to USABRDL for morphometric measurements and subsequent histological analysis. The histological analyses for the 6- and 9-month exposures were performed by Experimental Pathology Laboratories, Inc., Herndon, VA.

#### 4.1.6 Chemical Analyses

##### 4.1.6.1 Comprehensive Chemical Analyses

Comprehensive chemical analyses were performed four times at bimonthly intervals on 100, 10, and 1% groundwater by volume and APG-EA diluent water during the test periods shown in Table 1. The comprehensive chemical analyses included general water quality, metals, volatile organics, acid compounds, base/neutral compounds, pesticides, herbicides, organophosphorus pesticides, and munitions. The elements and/or compounds analyzed in each group are presented in the data tables discussed in Section 5.1.6.1. The 100% groundwater samples were grab samples taken directly from the well fed to the biomonitoring trailer. The 10 and 1% groundwater by volume samples were composite samples taken from the four 10 and 1% groundwater by volume replicate treatment tanks in the chronic histopathology study (Section 4.1.5). Grab samples of APG-EA diluent water were taken from a large polypropylene tank with a 99% particle replacement time of  $\approx 12$  h.

The groundwater and APG-EA diluent water samples were placed in appropriate containers for various analyses. The containers were placed on ice and delivered to a vendor for the analyses. The first comprehensive analysis was performed by Biospherics Inc., Laurel, MD, for all materials with the exception of the munitions. The remainder of the analyses were performed by Gascoyne Inc., Baltimore, MD, for all materials with the exception of the munitions. The methods used for the analyses of all materials are given in the data tables discussed in Section 5.1.6.1. The four munitions samples were analyzed by USABRDL via in-house procedures (U.S. Biomedical Research and Development Laboratory, 1993).

##### 4.1.6.2 Routine Water Quality Analyses

Routine water quality was measured in all histopathology treatment tanks. Dissolved oxygen, pH, and temperature were measured daily. Alkalinity, hardness, conductivity, total residual chlorine, free available chlorine, and total ammonia-nitrogen were measured once a week (all tests were performed on the same days). Unionized ammonia-nitrogen was determined by the method of Thurston et al. (1979). The methods used for the

analyses are presented in Section 5.1.6.2. The same methods used in the biomonitoring trailer were also used for the toxicity studies conducted at the University of Maryland Wye Research and Education Center.

In addition to the temperature measurements made in the aquaria during the chronic histopathology test, temperature was monitored continuously in Tank No. 3 via a strip chart recorder (Cole-Parmer Thermistor Recorder Model No. 08354-15, Cole-Palmer Instrument Co., Chicago, IL).

#### 4.1.7 Test Endpoints and Data Analyses

The test endpoint for the Microtox® 5- and 15-min EC50s was a reduction in bioluminescence. The EC50s and their 95% fiducial limits were determined by probit analysis using the software program supplied by Microtox® (Microtox®, 1988). The test endpoint for the acute effects of groundwater to the green alga was growth, measured as density (cells/mL). The 96-h EC50s for growth were estimated by using the "inhibition proportion" technique recommended by Horning and Weber (1985). The technique uses quantal analyses (e.g., probit or moving average angle methods) to estimate EC50s and their 95% fiducial or confidence limits. Since the assumptions of the quantal analysis are not met in the classical sense because of the very nature of the growth data, the count data at each treatment were averaged and subsequently converted to "inhibition proportions" using the formula below before a moving average angle analysis was performed (Stephan, 1978).

$$I = C - T / C * 100$$

where: C = the mean growth of the controls  
T = the mean growth at a given treatment

The 96-h EC50s and their 95% confidence limits for embryo malformations in the FETAX assays were determined by the moving average angle method using an EPA statistical program (Stephan, 1978). The test endpoint for all 24-h LC50 toxicity tests with rotifers, 48-h and 7-d LC50 tests with cladocerans, and 96-h and 7-d LC50 tests with fathead minnows was mortality. The LC50s and their 95% confidence limits were determined by the moving average angle method (Stephan, 1978).

The test endpoint for the chronic toxicity of groundwater at pH 4 and 7 to the green alga was growth measured as density (cells/mL). The no-observed-effect concentrations (NOEC) and lowest-observed-effect concentrations (LOEC) were determined by Dunnett's test. Dunnett's test consists of an analysis of variance (ANOVA) to determine the error term, which is then used in a multiple comparison test for comparing each of the treatment means with the control mean. The assumptions upon which the use

of Dunnett's test are contingent are that the observations within treatments are independent and normally distributed, with homogeneity of variance. The chi-square test for normality and Bartlett's test for homogeneity of variances were performed before the Dunnett's test was used. The above statistical tests were performed using Toxstat (Gulley et al., 1989) at a minimum probability level of 0.05.

The endpoints for the 7-d survival and reproduction tests with Ceriodaphnia were survival and young production. The endpoints for the fathead minnow 7-d survival and growth tests were survival and growth. The endpoints for the 96-h FETAX assay were survival and number of malformations. The statistics used for the LC50 data and FETAX EC50 (malformations) data are given above. NOECs and LOECs were determined as follows. The adult raw cladoceran survival data were analyzed by Fisher's Exact test. Arc-sine square root transformations were made on the FETAX percent embryo survival and percent embryo malformation data as well as the fathead minnow percent survival raw data before further data analyses were performed. With the exception of the cladoceran survival data, all data were then subjected to a chi-square test of normality and Bartlett's test for homogeneity of variance.

When the data sets met the assumptions of normality and homogeneity of variance, a parametric statistic was used. Dunnett's test was used when the number of replicates was constant among treatments. A t-test with Bonferroni adjustment of error rate was performed when the number of replicates was not constant among treatments. When a data set failed to meet the assumptions of normality or homogeneity of variance, a nonparametric statistic was used. Steel's Many-One Rank test was performed when equal number of replicates were used. The statistical tests were performed using Toxstat (Gulley et al., 1989). A minimum probability level of 0.05 was used for all tests.

The morphometric endpoints for the Japanese medaka chronic histopathology study after 6 and 9 months of exposure were wet weight and standard length. The raw data were first checked for normality and homogeneity of variance by the Kolmogorov-Smirnov test and Levene median test, respectively. The wet weight data after 6 and 9 months of exposure passed the tests for normality and homogeneity of variance and were subsequently analyzed by a general linear model type III test (replicates within treatment of the error term). The standard length data after 6 and 9 months of exposure were not normally distributed; thus, the nonparametric Kruskal Wallis one way ANOVA on ranks statistic was used. A statistically significant difference ( $\alpha = 0.05$ ) was found for length after 9 months of exposure using the nonparametric Kruskal Wallis test. Thus, Dunn's multiple comparison test was used to enumerate the difference between the

control and each experimental treatment. All statistical tests with the exception of the general linear model were performed via Sigma Stat (1992). The general linear model was run with SAS (1987). A minimum probability level of 0.05 was used for all tests. The histopathological data enumerated by Experimental Pathology Laboratory, Inc. at 6 and 9 months were not treated statistically.

## 4.2 Hazard Assessment Evaluation

The U.S. Army Aberdeen Proving Ground Directorate of Safety, Health, and Environment (DSHE) is conducting a risk assessment of the Canal Creek area as part of their Installation/Restoration Program. The potential hazard of the contaminated surficial aquifer at Beach Point, which appears to be an isolated part of the surficial aquifer identified throughout the Canal Creek area (Section 3.5), is being addressed by DSHE as an operable unit in a focus feasibility study of Beach Point. A hazard assessment of the contaminated surficial aquifer to aquatic organisms was performed in this study using the toxicity data obtained in the biomonitoring evaluation study. The ASTM Designation E 1023-84 (Reapproved 1988) standard guide for assessing the hazard of a material to aquatic organisms was used as the basis for the hazard assessment evaluation (ASTM, 1992b).

### 4.2.1 Scope of the Hazard Assessment

The hazard assessment process is complex and requires decisions at a number of points (ASTM, 1992b). The validity of a hazard assessment depends on the soundness of the decisions and the accuracy of information used. All decisions should be based on reasonable worst-case analyses so that an appropriate assessment can be completed for the least cost that is consistent with scientific validity. A number of worst-case assumptions were made for the Beach Point assessment when sufficient data were not available in order to err on the conservative side during the evaluation. The use of worst case assumptions obviously introduces a significant bias in the hazard assessment.

As discussed in the ASTM guide (ASTM, 1992b), the hazard assessment procedure is an iterative process for assessing the hazard of a material to aquatic organisms. The process basically considers the relationship between a material's measured or estimated environmental concentrations and the adverse effects likely to occur to aquatic organisms. Normally the iterative process proceeds as follows. Unavailable necessary information concerning environmental concentrations and adverse effects is obtained through a stepwise process that starts with inexpensive information gathering and progresses to more comprehensive data analyses and experimental studies if necessary. At the end of each iteration (usually a maximum of three) the estimated or measured environmental concentrations are compared with

information on possible adverse effects to determine the adequacy of the available data for assessing hazard. If it is not possible to conclude that hazard is either minimal or potentially excessive after an iteration, further iterations are conducted until the hazard is adequately characterized.

#### 4.2.2 Deviations from the Hazard Assessment Procedures

The hazard evaluation process for Beach Point deviated from some procedures recommended in the ASTM guide (ASTM, 1992b). Most of the deviations, all of which are discussed below, were dictated by the study site and the biomonitoring evaluation study design. The following deviations occurred. The ASTM guide was written for the hazard evaluation of specific chemicals or a group of chemicals that have similar biological, chemical, physical, and toxicological properties. The contaminated groundwater at Beach Point is a multiple mixture of heavy metals and chlorinated aliphatic compounds which have very different properties. Because the groundwater contained a mixture of contaminants, the complete mixture was tested rather than individual components of the mixture.

Aquatic toxicological models currently do not exist which allow for good predictions of toxicity for contaminant mixtures that contain chemicals with different modes of toxic action. Since the toxic interactions of the contaminants could not be readily determined, the concentrations of the groundwater chemicals were expressed as percent groundwater by volume rather than individual chemical mass. The mass of each contaminant in the groundwater, however, can be calculated from the chemical analysis data obtained during the biomonitoring phase of the study if desired.

The ASTM guide recommends a phased hazard iteration process (ASTM, 1992b). Several toxicological phases, however, were conducted simultaneously during the biomonitoring evaluation. That is, low-cost, medium-cost, and high-cost toxicological data collection/iteration phases were all conducted simultaneously during the biomonitoring evaluation studies.

Phase II (medium-cost information) and Phase III (high-cost information) of the ASTM hazard assessment recommend that acute and chronic toxicity tests, respectively, be conducted with estuarine organisms when a material enters estuarine waters. The Bush River is a low salinity estuary at Beach Point (Carter, 1976); however, all of the biomonitoring studies were conducted with freshwater organisms. Tests with estuarine organisms were initially considered in the design phase of the biomonitoring study. However, the pH of the groundwater at Beach Point was  $4 \pm 0.1$ . Preliminary pH adjustment studies in freshwater showed that some heavy metals were "salted out" of solution when the pH was raised from 4 to 7. The "salting out" effect observed in



freshwater would increase at a salinity of 20 ppt which is the test salinity normally required for the EPA acute and short-term chronic test methods for estuarine organisms (Weber, 1991; Weber et al., 1989). Several heavy metals in the groundwater occurred at concentrations which could be toxic (U.S. EPA, 1986b); thus, a decision was made not to conduct estuarine tests because the tests would have underestimated the toxicity of the complex chemical mixture of the contaminants. As will be shown in the Results and Discussion Section, less toxicity occurred in several of the freshwater biomonitoring tests conducted at pH 7 relative to those conducted at pH 4. Finally, the State of Maryland Code (COMAR) considers the Bush River Area (Sub-Basin 26.08.02.03-1B) as "freshwater" for the purposes of applying numerical toxic substance criteria (see Section 5.2.3.1).

One can argue that differences exist between the toxicological sensitivities of freshwater and saltwater organisms. Indeed, there is no question that examples could be given to support either side of the argument with individual materials present in the groundwater at Beach Point. EPA has developed both freshwater and saltwater numerical water quality criteria for most of the priority pollutant heavy metals present in the groundwater at Beach Point (U.S. EPA, 1986b). As one would predict from the general toxicological literature, differences exist between EPA's freshwater and saltwater acute and chronic criteria for the various metals. Little research has been conducted on the comparative sensitivities of freshwater versus saltwater organisms exposed to multiple mixtures of heavy metals and aliphatic organics. Since toxicological differences exist between various freshwater and saltwater organisms and few data are available to predict differences in multiple mixtures, we assumed that the freshwater biomonitoring organisms would serve as reasonable surrogates for estuarine organisms in the Bush River.

It is known that the groundwater enters the Bush River through the bottom sediments (Section 3.5). One could argue that benthic as well as water column organisms should also be included in the suite of test organisms. No benthic organisms were tested in the biomonitoring evaluation of the groundwater. A recent analysis of numerical water quality criteria chemicals by EPA shows that freshwater and saltwater benthic organisms, in general, have toxicological sensitivities similar to those of water column organisms (U.S. EPA, 1993a). Thus, toxicity data for water column organisms were used to predict toxicity for benthic organisms.

#### 4.2.3 Estimated Discharge Rate of the Surficial Aquifer

The discharge rate of the Beach Point surficial aquifer to the Bush River had to be estimated in order to estimate the environmental concentrations of the groundwater in the Bush

River. An estimated discharge rate of the surficial aquifer at Beach Point was made by Jacobs Engineering Group (JEG, 1994). The horizontal transport value,  $V_{hor}$ , for the discharge calculation was taken from a 25-h study conducted in late March 1994 by K-V Associates, Inc. (1994).  $V_{hor}$ , which was 0.27 m/d (0.89 ft/d) in a direction of 61.8°NE magnetic north, approximately 24° riverward from the main peninsula axis, was taken from well CC-33B.1 which is an intermediate depth well at Beach Point (Section 3.3). The assumption was made that  $V_{hor}$  was continuous throughout the surficial aquifer at Beach Point (JEG, 1994).  $V_{hor}$  orientation (flow direction) was assumed to be consistent with actual aquifer conditions over one complete tidal cycle (discounting short-term fluctuations due to tidal changes).

The flowing assumptions were also made for the calculation of the estimated discharge rate of the surficial aquifer at Beach Point (JEG, 1994). The surficial aquifer was considered to be homogeneous, characterized by isotropic flow conditions. The average saturated thickness of the aquifer was assumed to be 18.8 m (61.8 ft). The Bush River frontage along the peninsula is ≈448 m (1,470 ft). Approximately 366 m (1,200 ft) of frontage is directed in a NE direction; approximately 82 m (270 ft) of the northern peninsula terminus is directed in a NW direction. The aquifer was assumed to discharge the entire length of the Beach Point Peninsula fronting the Bush River. Thus, the cross-sectional area of saturated surficial aquifer fronting Bush River was assumed to be ≈8,443 m<sup>2</sup> (90,883 ft<sup>2</sup>). The length and area of the aquifer fronting the Bush River are believed to be quite conservative. A more realistic estimate of length of discharge from Beach Point is probably one third to one half, rather than the entire length (Lorah, 1994). The directional component of  $V_{hor}$  orthogonal to the Bush River frontage was used rather than assuming  $V_{hor}$  is orientated perpendicular (orthogonal) to the Bush River frontage in the surficial aquifer. That is, the measured horizontal velocity (0.27 m/d) was multiplied by a sin (24°) factor along the 366 m (1,200 ft) frontage.

The calculation of the estimated discharge rate of the surficial aquifer to the Bush River made by Jacobs Engineering Group (JEG, 1994) is:

$$\begin{aligned} \text{Discharge} &= (0.27 \text{ m/d velocity})(\sin 24^\circ)(18.8 \text{ m depth})(366 \text{ m frontage}) + (0.27 \text{ m/d velocity})(18.8 \text{ m depth})(82 \text{ m frontage}) \\ &= 1,175.5 \text{ m}^3/\text{d} \quad (41,508.7 \text{ ft}^3/\text{d}) \end{aligned}$$

#### 4.2.4 Contaminant Distribution Assumptions in the Groundwater

As discussed in Section 3.3, chemical monitoring of the wells at Beach Point showed that the highest concentrations of heavy metals in 1988 occurred in the mid-depth (CC-33B.1) and deep (CC-33B) wells. The highest concentrations of chlorinated aliphatic organics occurred primarily in the deep well as a residual DNAPL plume. Only one shallow well (CC-33A) and one deep well (CC-33B) were studied at Beach Point during 1989. The concentrations of heavy metals and volatile organics were all higher in the deep well (CC-33B) than in the shallow well (CC-33A).

The following assumptions were made for the hazard assessment. The assumption was made for heavy metals that no retardation occurred via adsorption onto solid surfaces or trapping by clays through ion exchange. It was also assumed that no precipitation of the metals occurred when the pH shifted from 4 to neutrality when the groundwater entered the receiving stream. With regard to the DNAPLs, the assumption was made that no abiotic (chemical) or biotic (microbial) transformations occurred. We assumed that the heavy metals and residual DNAPLs were homogeneously mixed throughout the complete aquifer. In addition, the highest concentration (not the average concentration) of each contaminant measured during the four bimonthly chemical analyses (Section 4.1.6.1) was assumed to be homogeneously distributed throughout the aquifer. It was also assumed that the maximum concentrations of materials would not increase above those currently present in well CC-33B since the original sources of the contaminants were not longer present (Section 3.2). The assumption was made that the highest concentrations of the heavy metals and chlorinated aliphatics in the aquifer all moved through the sediments into the Bush River. Finally, the assumption was made that 1,176 m<sup>3</sup>/d of contaminated groundwater moved into the Bush River. We are aware that some of the groundwater flow, which is influenced by tidal stage, may be in the direction of Kings Creek (Section 3.5).

#### 4.2.5 Screening-level Assessment of the Near-Field Dilution of the Groundwater Plume in Bush River

A screening level assessment of the near-and far-field dilution of the groundwater discharge from Beach Point was conducted by Najarian Associates, Inc. (1994) under contract to USABRDL. The primary objective of the study was to estimate, using EPA-approved screening-level techniques, the initial ("near-field") dilution and flushing rate ("far-field" dilution) of the groundwater discharge plume into the Bush River. The assessment, when combined with the discharge concentration data, provides first-order estimates of near-field concentrations. That is, it gives receiving water concentrations that would be

expected over relatively short distances from the discharge site (e.g., ones, tens, and hundreds of meters) and over short time periods (e.g., seconds and minutes).

The second objective was to compute concentrations for selected toxic constituents and to compare the results to available baseline data. As a result, potential water quality impacts can be quantified. The third objective was to assess the applicability of a Maryland "regulatory mixing zone", i.e., a localized discharge zone in which local water quality standards may be exceeded (U.S. EPA, 1991a). Such zones are routinely allowed for wastewater treatment plant discharges. If applicable to the Beach Point groundwater discharge plume, a mixing zone may allow for local exceedences of water quality standards.

#### 4.2.5.1 Near-field Dilution Estimates

The near-field model approach was to evaluate the volume of groundwater emanating from Beach Point as a function of the potential dilution available within the Bush River. Within the near-field, it was postulated that the groundwater plume intersects the channel of the Bush River and seeps into the River as a submerged buoyant plume. Based on the available geologic information about the site, it was assumed the discharge from the surficial aquifer was limited to a relatively narrow band that parallels the interface between the Bush River and the Beach Point Peninsular. Since the groundwater plume is less dense (less saline) than the adjacent estuarine water, it would rise and subsequently mix with the ambient receiving waters. Thus, it would be diluted through mechanisms of buoyancy-based entrainment and mixing associated with ambient currents.

As discussed in Najarian Associates, Inc. (1994), the same physical mechanisms are known to dilute effluent plumes discharged from outfall diffusers of wastewater treatment plants (WWTP) and electrical generation facilities. Thus, the dilution of groundwater emanating from Beach Point can be conceptualized as the dilution of a discharge from a line diffuser. This approach allows the near-field impact of the groundwater discharge to be simulated using established plume dilution models that have been developed primarily for such outfall diffusers.

The limitations of the approach are twofold. First, most plume dilution models also simulate momentum-based entrainment, a phenomenon that has a negligible effect upon the groundwater plume. Therefore, the port configuration on the conceptualized line diffuser must be set to minimize initial momentum. Secondly, the conceptualization of the groundwater discharge surface as a line diffuser will concentrate the plume's impact within the near-field condition. As this effect reduces the dimensions of the near-field plume and calculated levels of dilution, the model result will provide a conservative estimate

of field conditions.

A series of EPA-approved, plume dilution models for surface waters are given in Muellenhoff et al. (1985). The EPA models are usually applied to discharges from line sources such as outfall diffuser manifolds. In the present case, however, the groundwater discharge is emanating from the river bed. While all EPA-approved plume models could be run, ULINE (uniform linear density flume model) was selected for the dilution calculations because it is based directly on laboratory experiments and has proved it's usefulness in recent outfall studies conducted throughout the United States (Najarian Associates, Inc., 1994). The ULINE model also neglects initial discharge momentum which is consistent with the groundwater plume movement into the Bush River. The ULINE model is designed to give dilution ratios of a discharge in a receiving stream; not distance isopleths from the source of a discharge.

Outfall dilution studies are typically conducted under "critical" minimum dilution conditions (Najarian Associates, Inc., 1994). These conditions are defined as the lowest 10th percentile ambient currents, and highest 10th percentile ambient density stratification conditions. However, Maryland regulations require that the acute aquatic life toxicity criteria be applied under conditions of mean low water and "minimum daily averaged 1-h tidal velocity" (near slack tide) (COMAR 26.08.02.05C); chronic aquatic life criteria are applied under conditions of mean water level and average tidal velocity (COMAR 26.08.02.05D). Thus, the input data were selected for the ULINE near-field model to reflect these required conditions.

To adapt ULINE to the study area, an input of site-specific data was required. The model input data fell into three categories which included 1) groundwater discharge parameters; 2) receiving water parameters; and 3) outfall diffuser parameters. The estimation of the groundwater input parameters were those given in Section 4.2.3. The ambient receiving water input parameters (e.g., ambient current velocity, salinity, temperature, and depth of discharge in the Bush River) are given in Najarian Associates, Inc. (1994). The conceptualized outfall discharge parameters for an assumed 448-m line source of buoyancy are also given in Najarian Associates, Inc. (1994).

#### 4.2.5.2 Far-field Dilution Estimates

The Bush River receiving waters can be divided into two zones based on physical mechanisms of mixing. In the near-field, rapid mixing is caused primarily by the discharge plumes's buoyancy and initial discharge momentum, in combination with ambient currents. In the far-field, the plume is mixed passively by ambient processes such as turbulence and tidal dispersion. Far-field length scales are typically kilometer distances from

the discharge site; far-field time scales are hours, days, or longer.

Three EPA methods were initially considered for the far-field dilution estimates (i.e., the flushing rate) in the Bush River (U.S. EPA, 1985b). Far-field dilutions were calculated and reported by Najarian Associates, Inc. (1994) for the Bush River via the three methods, which included the tidal prism method, fraction of freshwater method, and dye-tracer method. The dye-tracer method was selected for further computations because dye-tracer data collected by Carter (1976) for the Bush River provided a more conservative estimate of the far-field dilution than the first two models which were based on segmented (complete mixing) approaches.

Total near-field dilutions, which correct for the influence of far-field dilutions (Fisher et al., 1979), were calculated for Maryland's acute and chronic aquatic life toxicity criteria under Spring and Fall conditions. The smaller of the Spring or Fall calculated dilution factors for both the acute and chronic toxicity conditions were then used to estimate the near-field acute and chronic receiving water concentrations of all the contaminants found in the Beach Point groundwater. The estimate for each contaminant was determined by using the highest concentration of the material found in the groundwater (see Section 4.2.4) divided by the dilution factor.

#### 4.2.5.3 Mixing Zone Consideration

Mixing zones are areas where an effluent discharge undergoes initial dilution; they may also be extended to cover secondary mixing in the ambient waterbody. A mixing zone is an allocated impact zone where acute and chronic water quality criteria can be exceeded as long as a number of protections are maintained as required by EPA and the State (U.S. EPA, 1991a). The State of Maryland allows a mixing zone as a policy issue, but requires spatial dimensions to limit the areal extent of the mixing zone. Mixing zones may be allowed on a case-by-case basis. The concept of mixing zones is normally applied in the case of wastewater treatment facilities and power plants that discharge to waterways. Arguments will be presented in Section 5.2.3 that the mixing zone concept could be considered for the groundwater discharge in the Bush River.

## SECTION 5

### RESULTS AND DISCUSSION

#### 5.1 Biomonitoring Evaluation

The Results and Discussion Section is organized as follows. The results and discussion for all of the biomonitoring systems are presented in separate sections for each test system. The endpoints/responses for each biomonitoring toxicity test are summarized in Table 2. The table is organized as Tests Nos. 1, 2, 3, and 4 which reflects the bimonthly test design. The Microtox®, Japanese medaka LC50, Ames, SCE, and Japanese medaka chronic histopathology and morphometric results are presented under the Test No. 1 column for space convenience purposes only; the tests were not quarterly tests as the heading implies. The raw data, water quality data, and statistical analyses for the biomonitoring test systems as well as the chemical analyses results are given in separate Appendices as referred to in the appropriate sections for each test system.

##### 5.1.1 Acute Toxicity Tests

###### 5.1.1.1 Microtox®

A summary of the Microtox® 5- and 15-min EC50 (reduction of bioluminescence) results is given in Table 2. The test data for the 100, 10, and 1% groundwater by volume samples, as well as the APG-EA diluent water are given in Appendix 1, Tables A1-1 to A1-4, respectively. The data for the Microtox® assays conducted on the groundwater buffered to a pH of  $\approx 7$  and the pH of the samples used in the assays are given in Appendix 2, Tables A2-1 and A2-2.

The Microtox® 5- and 15-min EC50s for 100% groundwater at pH 4 ranged from 10.6-29.1 and 17.0-45.2% groundwater by volume, respectively (Table 2). The 5- and 15-min EC50s for the 100% groundwater adjusted to pH 7 ranged from 16.9-59.1 and 18.4-95.6% groundwater by volume, respectively. The raw groundwater was less toxic at pH 7 than at pH 4. Although the 5- and 15-min EC50s were variable over the course of the study, the raw and buffered groundwater both appeared to become less toxic as the study progressed (Fig. 1 and 2). As will be shown below, the same trend was not evident in the other acute and short-term chronic test systems. Less toxicity was observed in the 15-min EC50s relative to the 5-min EC50s.

Toxicity was detected in 10% groundwater by volume one time during the study. The 5-min EC50 was 98.6% groundwater by volume; no 15-min EC50 was obtained for the same sample. The EC50 is most likely spurious because the 95% fiducial limits ranged from 88 to 300% groundwater by volume. No toxicity was

TABLE 2. SUMMARY OF THE TOXICITY ENDPOINTS/RESPONSES FOR BIOMONITORING TESTS CONDUCTED ON BEACH POINT GROUNDWATER (WELL CC-33B) FROM FEBRUARY 1993 TO DECEMBER 1993

Bioassay	Endpoint	Value <sup>a</sup>			
		Test No. 1	Test No. 2	Test No. 3	Test No. 4
Microtox®:					
100% (pH 4)	5-min EC50 <sup>b</sup>	10.6-29.1	N/A	N/A	N/A
100% (pH 7)	5-min EC50 <sup>b</sup>	16.9-59.1	N/A	N/A	N/A
100% (pH 4)	15-min EC50 <sup>b</sup>	17.0-45.2	N/A	N/A	N/A
100% (pH 7)	15-min EC50 <sup>b</sup>	18.4-95.6	N/A	N/A	N/A
10%	5-min EC50 <sup>b</sup>	98.6 <sup>c</sup>	N/A	N/A	N/A
10%	15-min EC50 <sup>b</sup>	Not toxic	N/A	N/A	N/A
1%	5-min EC50 <sup>b</sup>	Not toxic	N/A	N/A	N/A
1%	15-min EC50 <sup>b</sup>	Not toxic	N/A	N/A	N/A
Diluent H <sub>2</sub> O	5-min EC50 <sup>b</sup>	Not toxic	N/A	N/A	N/A
Diluent H <sub>2</sub> O	15-min EC50 <sup>b</sup>	Not toxic	N/A	N/A	N/A
Rotifer:					
pH 4	24-h LC50	72	64	70	95
pH 7	24-h LC50	Not toxic	No LC50	No LC50	Not toxic
Green alga:					
pH 4	96-h EC50 <sup>d</sup>	59	51	56	55
pH 4	NOEC <sup>d</sup>	56	18	18	18
pH 4	LOEC <sup>d</sup>	100	32	32	32
pH 7	96-h EC50 <sup>d</sup>	No EC50	58	55	50
pH 7	NOEC <sup>d</sup>	56	32	18	18
pH 7	LOEC <sup>d</sup>	100	56	32	32



TABLE 2. (CONTINUED)

Bioassay	Endpoint	Value <sup>a</sup>			
		Test No. 1	Test No. 2	Test No. 3	Test No. 4
Cladoceran:					
pH 4	48-h LC50	65	65	65	63
pH 4	7-d LC50	65	65	65	42
pH 4	NOEC <sup>e</sup>	18	10	10	10
pH 4	LOEC <sup>e</sup>	32	18	18	18
pH 7	48-h LC50	Not toxic	Not toxic	No LC50	No LC50
pH 7	7-d LC50	43	72	No LC50	40
pH 7	NOEC <sup>e</sup>	f	g	10	10
pH 7	LOEC <sup>e</sup>	f	g	18	18
Fathead minnow:					
pH 4	96-h LC50	64	22	45	62
pH 4	7-d LC50	62	22	39	51
pH 4	NOEC <sup>h</sup>	32	10	32	32
pH 4	LOEC <sup>h</sup>	56	18	56	56
pH 7	96-h LC50	Not toxic	Not toxic	Not toxic	Not toxic
pH 7	7-d LC50	Not toxic	No LC50	Not toxic	Not toxic
pH 7	NOEC <sup>h</sup>	56	56	Not toxic	Not toxic
pH 7	LOEC <sup>h</sup>	100	100	Not toxic	Not toxic
Japanese medaka:					
pH 4	96-h LC50	No LC50	N/A	N/A	N/A

TABLE 2. (CONTINUED)

Bioassay	Endpoint	Value <sup>a</sup>			
		Test No. 1	Test No. 2	Test No. 3	Test No. 4
Ames:					
100%	Mutagenicity	i	i	Negative	Negative
100% (10X)	Mutagenicity	i	i	Negative	Negative
10%	Mutagenicity	Negative	Negative	Negative	Negative
10% (10X)	Mutagenicity	Negative	Negative	Negative	Negative
1%	Mutagenicity	Negative	Negative	Negative	Negative
1% (10X)	Mutagenicity	Negative	Negative	i	i
Diluent H <sub>2</sub> O	Mutagenicity	Negative	Negative	Negative	Negative
Diluent H <sub>2</sub> O (10X)	Mutagenicity	Negative	Negative	Negative	Negative
SCE:					
100% (Conc)	DNA damage	Positive	N/A	N/A	N/A
100%	DNA damage	Negative	N/A	N/A	N/A
10% (Conc)	DNA damage	Negative	N/A	N/A	N/A
Diluent H <sub>2</sub> O (Conc)	DNA damage	Negative	N/A	N/A	N/A
FETAX:					
pH 4	4-d LC50	Not toxic	Not toxic	Not toxic	No LC50
pH 4	4-d EC50 <sup>j</sup>	No EC50	89	No EC50	No EC50
pH 4	NOEC <sup>k</sup>	10	10	10	32
pH 4	LOEC <sup>k</sup>	18	18	18	56
pH 7	4-d LC50	Not toxic	No LC50	Not toxic	No LC50
pH 7	4-d EC50 <sup>j</sup>	No EC50	No EC50	No EC50	No EC50
pH 7	NOEC <sup>k</sup>	18	18	18	18
pH 7	LOEC <sup>k</sup>	32	32	32	32

TABLE 2. (CONTINUED)

Bioassay	Endpoint	Value <sup>a</sup>			
		Test No. 1	Test No. 2	Test No. 3	Test No. 4
Chronic histopathology and growth:					
10%	6/9-m Wet weight	No effect	N/A	N/A	N/A
1%	6/9-m Wet weight	No effect	N/A	N/A	N/A
Diluent H <sub>2</sub> O	6/9-m Wet weight	N/A	N/A	N/A	N/A
10%	6/9-m Std. lgth.	No effect	N/A	N/A	N/A
1%	6/9-m Std. lgth.	No effect	N/A	N/A	N/A
Diluent H <sub>2</sub> O	6/9-m Std. lgth.	N/A	N/A	N/A	N/A
10%	6/9-m Lesions	Negative <sup>1</sup>	N/A	N/A	N/A
1%	6/9-m Lesions	Negative <sup>1</sup>	N/A	N/A	N/A
Diluent H <sub>2</sub> O	6/9-m Lesions	Negative <sup>1</sup>	N/A	N/A	N/A

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<sup>a</sup> All endpoints are given as percent groundwater by volume.

<sup>b</sup> Range of all EC50s for reduction in bioluminescent activity conducted from April-December.

<sup>c</sup> Only one 5-min EC50 for reduction in bioluminescent activity occurred during the quarter.

<sup>d</sup> Test endpoint- reduction in growth (cell density).

<sup>e</sup> Test endpoint- reduction in neonate production.

<sup>f</sup> The NOEC and LOEC could not be obtained because significant ( $\alpha = 0.05$ ) reductions in neonate production relative to the controls occurred at all concentrations down to 32% buffered groundwater by volume, which was the lowest concentration studied.

<sup>g</sup> The NOEC and LOEC could not be obtained because significant ( $\alpha = 0.05$ ) reductions in neonate production relative to the controls occurred at all concentrations down to 18% buffered groundwater by volume, which was the lowest concentration studied.

<sup>h</sup> Test endpoint- reduction in growth (dry weight) for Test Nos. 1 and 2 at pH 4 and Test No. 1 at pH 7; the test endpoint for Test Nos. 3 and 4 at pH 4 and Test No. 2 at pH 7 was an increase in mortality rather than a reduction in growth.

TABLE 2. (CONTINUED)

Bioassay	Endpoint	Value <sup>a</sup>			
		Test No. 1	Test No. 2	Test No. 3	Test No. 4
i	Assay not conducted.				
j	96-h EC50 for malformations.				
k	Test endpoint- increased number of malformations.				
l	See Section 5.1.5 for additional information.				

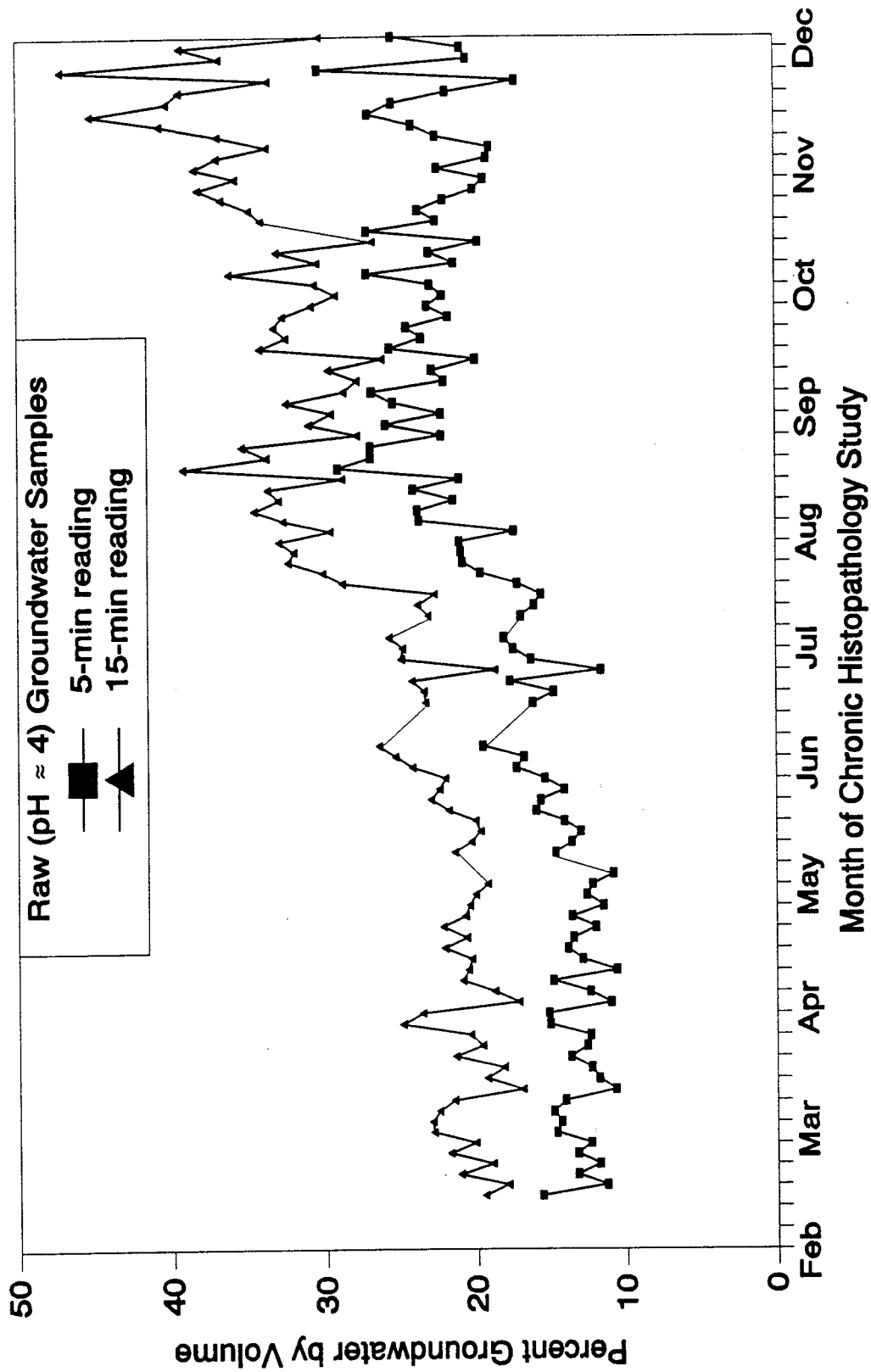


Figure 1. Microtox® test results of raw (pH  $\approx$  4) groundwater samples taken during the chronic histopathology study.

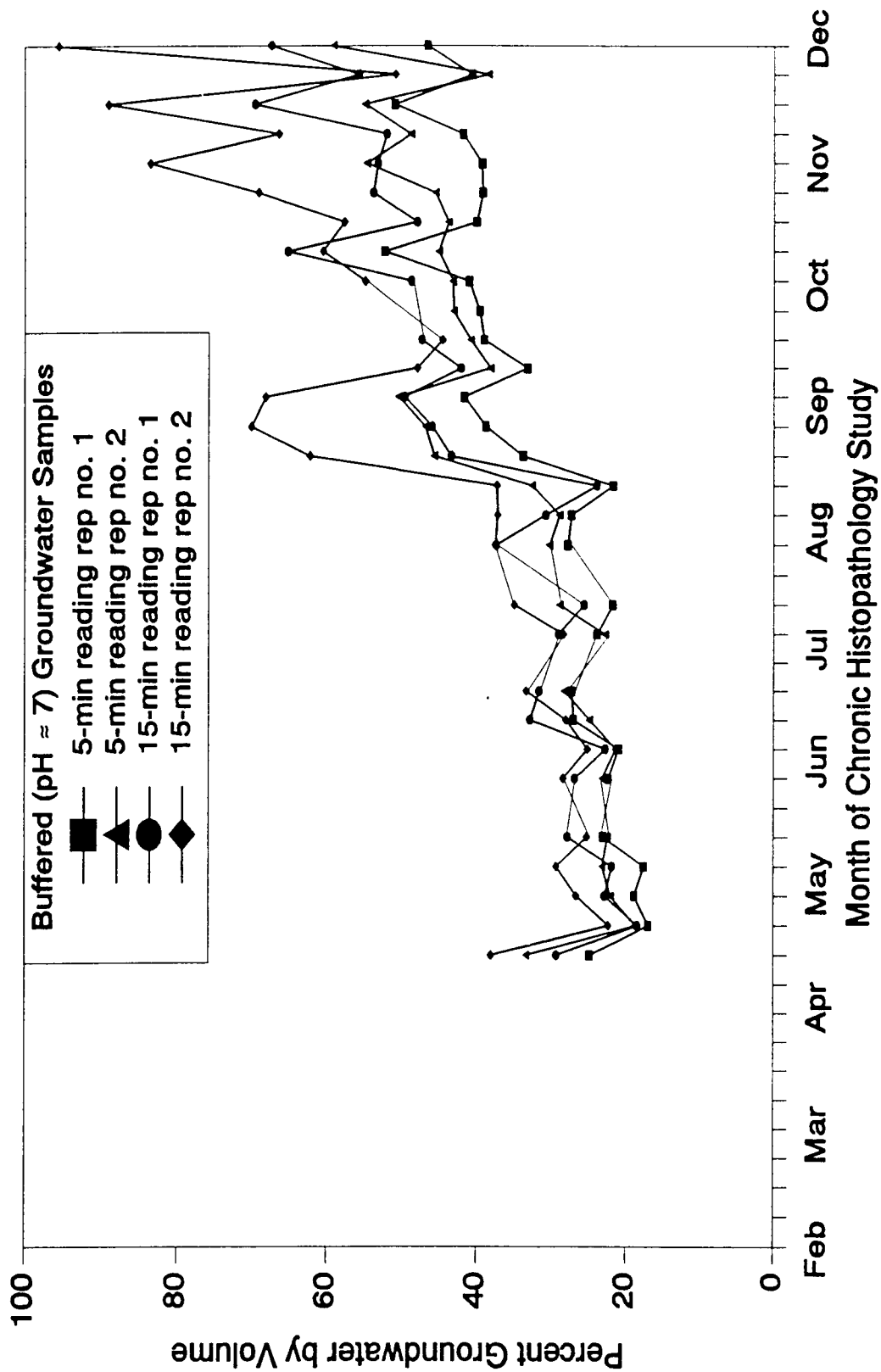


Figure 2. Microtox® test results of buffered (pH ≈ 7) groundwater samples taken during the chronic histopathology study.

detected during the study in the 1% groundwater by volume samples or the APG-EA diluent water.

The toxicity of the groundwater as shown by the Microtox® assay is not surprising when one considers the complex mixture of the contaminants in the groundwater (Section 5.1.6.1; Table 3). For example, the 5-min EC50s for both copper and zinc are less than the groundwater concentrations shown in Table 3 (Qureshi et al., 1982). Similarly, several of the volatile organics at concentrations below the concentrations in the raw groundwater have been shown to be toxic via the 5- and/or 15-min Microtox® analysis (Kaiser and Ribo, 1988). Chloroform, chlorobenzene, trichloroethane, and tetrachloroethane all have 5- and/or 15-min EC50s below the concentrations found in the groundwater.

#### 5.1.1.2 Rotifer

The results of the 24-h LC50 tests at pH 4 and 7 with the rotifer are summarized in Table 2. The test data for Test Nos. 1, 2, 3, and 4 at pH 4 and 7 are given in Appendices 3 and 4, 5 and 6, 7 and 8, and 9 and 10, respectively. The 24-h LC50 values for the four acute rotifer tests conducted at pH 4 ranged from 64-95% groundwater by volume. No toxicity was found at pH 7 in the first and fourth bimonthly tests. Some mortality occurred in the 100% groundwater treatment during the second and third tests; however, no LC50s could be calculated.

#### 5.1.1.3 Green Alga, Cladoceran, Fathead Minnow, and Japanese Medaka

The 96-h EC50s (reduction in growth) for the green alga exposed to raw groundwater at pH 4 and buffered groundwater at pH 7 are given in Table 2. The raw data at pH 4 and 7 for Test Nos. 1-4 are given in Appendices 11-18. The 96-h EC50s for reduction in growth at pH 4 ranged from 51-59% groundwater by volume (Table 2). With the exception of Test No. 1 in which no EC50 could be calculated because <50% reduction in growth occurred in the study, the 96-h EC50s were essentially the same in the groundwater buffered to pH 7. The EC50s at pH 7 in Test Nos. 2-4 ranged from 50-58% groundwater by volume.

The 48-h acute LC50 toxicity data for the cladoceran at pH 4 and 7 are summarized in Table 2. The raw data, including test water quality, for Test Nos. 1-4 at pH 4 and 7 are given in Appendices 19-26. Groundwater at pH 4 was acutely toxic to the cladoceran (Table 2). The 48-h LC50s ranged from 63-65% groundwater by volume for the four tests. Buffered groundwater was not toxic in Test Nos. 1 and 2. Some toxicity occurred in Tests Nos. 3 and 4; however, no 48-h LC50 could be calculated because <50% mortality occurred in 48 h.

TABLE 3. SUMMARY OF THE FOUR BIMONTHLY CHEMICAL ANALYSES  
(RANGE OF CONCENTRATIONS) CONDUCTED ON RAW BEACH  
POINT GROUNDWATER (WELL CC-33B) FROM FEBRUARY  
1993 TO DECEMBER 1993

Parameter	Concentration	Unit
<u>General Water Quality</u>		
Alkalinity	<1 - 21	mg/L as CaCO <sub>3</sub>
Hardness	170 - 230	mg/L as CaCO <sub>3</sub>
Conductivity	1,600 - 2,020	μs/cm
Total Suspended Solids	<5	mg/L
Total Organic Carbon	2 - 4	mg/L
Calcium	16.5 - 21	mg/L as Ca
Magnesium	30 - 43	mg/L as Mg
Manganese	1.7 - 2.1	mg/L as Mn
Potassium	2.5 - 4.1	mg/L as K
Sodium	257 - 350	mg/L as Na
Sulfate	62 - 91	mg/L as SO <sub>4</sub>
Sulfide	<1	mg/L as S
Chloride	490 - 580	mg/L as CL
Ammonia-Nitrogen	<0.1	mg/L as N
Nitrate-Nitrogen	0.1 - 2.5	mg/L as N
Nitrite-Nitrogen	<0.01	mg/L as N
Phosphorus	0.12 - 2.64	mg/L as P
Fluoride	0.2 - 1.2	mg/L as F
Iron	4.6 - 7.7	mg/L as Fe
Cyanide	<0.01 - 0.06	mg/L as CN
Bromide	0.4 - 1.5	mg/L as Br
pH	3.9 - 4.1	Std. Unit



TABLE 3. (CONTINUED)

Parameter	Concentration	Unit
<u>Heavy Metals<sup>a</sup></u>		
Aluminum	810 - 1,500	µg/L as Al
Antimony	<5	µg/L as Sb
Arsenic	<5-7	µg/L as As
Beryllium	<5	µg/L as Be
Boron	50 - 70	µg/L as B
Cadmium	0.8 - 1.4	µg/L as Cd
Chromium	<2	µg/L as Cr
Cobalt	80 - 110	µg/L as Co
Copper	5.4 - 8	µg/L as Cu
Lead	<5	µg/L as Pb
Mercury	<0.5	µg/L as Hg
Molybdenum	<10	µg/L as Mo
Nickel	120 - 180	µg/L as Ni
Selenium	<5	µg/L as Se
Silver	<1	µg/L as Ag
Thallium	<5	µg/L as Tl
Tin	<50	µg/L as Sn
Zinc	210 - 310	µg/L as Zn
<u>Volatile Organics</u>		
Chlorobenzene	2	µg/L
Chloroform	10 - 12	µg/L
1,1,2-Trichloroethane	37 - 110	µg/L
1,1,1,2-Tetrachloroethane	3	µg/L
1,1,2,2-Tetrachloroethane	9,000 - 17,000	µg/L

TABLE 3. (CONTINUED)

Parameter	Concentration	Unit
<u>Volatile Organics Con't</u>		
1,1-Dichloroethene	1	µg/L
cis-1,2-Dichloroethene	110 - 640	µg/L
Trichloroethene	450 - 1,600	µg/L
Tetrachloroethene	30 - 90	µg/L
Vinyl Chloride	2	µg/L

<sup>a</sup> The metal concentrations are total metal; not dissolved metal.

The 96-h LC50 data for the fathead minnow at pH 4 and 7 are summarized in Table 2. The raw data, including test water quality, for Test Nos. 1-4 at pH 4 and 7 are given in Appendices 27-34. Groundwater at pH 4 was acutely toxic to the fathead minnow (Table 2). The 96-h LC50s ranged from 22-64% groundwater by volume for the four tests. Buffered groundwater at pH 7 was not toxic in any test after a 96-h exposure.

One 96-h LC50 toxicity test was conducted with Japanese medaka at pH 4 (Table 2; Appendix 35). The groundwater was toxic at pH 4 after a 96-h exposure; however, a 96-h LC50 could not be calculated because <50% mortality occurred in 96 h. An acute toxicity test was not conducted at pH 7 since the groundwater was not acutely toxic to Japanese medaka at pH 4.

The acute toxicity of the groundwater to the rotifer, cladoceran, and fathead minnow at pH 4 may be attributable to the heavy metals in the groundwater (Table 3). Several EPA priority pollutant heavy metals (cadmium, copper, nickel, and zinc) were found in the groundwater. The concentration of zinc in the groundwater (when adjusted for hardness) exceeded the EPA numerical water quality criterion of 120 µg/L for freshwater invertebrates and fish (U.S. EPA, 1987). Furthermore, metals such as copper and zinc exist primarily as divalent cations at a pH of 4 which is the most toxic form of the metal (Lee, 1973; Sprague, 1985). It is well established that the toxicity of metals in chemical mixtures is additive for many aquatic animals (Marking, 1985). It is likely that the toxicity observed in the study may have been additive or greater than additive (de March,

1988). The reduction and/or elimination of toxicity at pH 7 for the same test organisms is most likely related to the reduction in toxicity of heavy metals as they shift from a divalent cation at pH 4 to less toxic species at pH 7 (Lee, 1973). In contrast to the acute toxicity of the groundwater at pH 4 to the rotifer, cladoceran, and fathead minnow, a 96-h LC50 could not be calculated for the Japanese medaka because <50% mortality occurred.

No single heavy metal at the concentrations present in the groundwater can account for the toxicity observed in the green alga (U.S. EPA, 1986b). Few data are available on the possible joint toxicity of heavy metals or organics to green algae (Faust et al., 1994). The toxicity at pH 4 and 7 was essentially the same (Table 2) which suggests that heavy metals may not be important toxicologically to the alga. No single priority pollutant organic for which there are toxicity data can account for the toxicity observed in the alga (U.S. EPA, 1986b). One can only speculate that the toxicity of the groundwater to the alga may be related to 1) the joint toxicity of the metals, 2) joint toxicity of the organics and/or 3) interaction of the metals and organics.

#### 5.1.2 Short-term Chronic Toxicity Tests

##### 5.1.2.1 Green Alga

The NOECs and LOECs (reduction in cell density) for the green alga exposed to groundwater at pH 4 and 7 are summarized in Table 2. The test data and statistical analyses for Test Nos. 1-4 are given in Appendices 11-18. At pH 4, the NOECs for the four tests ranged from 18-56% groundwater by volume. The LOECs ranged from 32-100% groundwater by volume. At pH 7, the NOECs and LOECs, respectively, ranged from 18-56 and 32-100% groundwater by volume. With the exception of Test No. 2, the NOECs and LOECs were exactly the same at pH 4 and 7 for the same test period. The NOECs and LOECs were less at pH 7 than at pH 4 in Test No. 2 only. Thus, with the exception of one test, no difference in algal toxicity was found for groundwater at pH 4 and pH 7. Some variation in toxicity was found between the four sets of tests. The lowest NOEC found in any test was 18% groundwater by volume. As stated above in Section 5.1.1.3, one can only speculate that the toxicity of the groundwater to the alga may be related to the 1) joint toxicity of the metals, 2) joint toxicity of the organics and/or 3) interaction of the metals and organics.

##### 5.1.2.2 Cladoceran

The 7-d LC50s, NOECs, and LOECs for the cladoceran exposed to groundwater at pH 4 and 7 are summarized in Table 2. The test data and statistical analyses for Test Nos. 1-4 are given in Appendices 19-26. The groundwater at pH 4 was toxic in all

tests. The short-term chronic 7-d LC50s at pH 4 ranged from 42-65% groundwater by volume. The NOECs (reduction in neonate production) at pH 4 ranged from 10-32% groundwater by volume while the LOECs ranged from 18-32% groundwater by volume in the four tests.

The groundwater at pH 7 was essentially as toxic to the cladoceran as it was at pH 4. The 7-d LC50s ranged from 40-72% groundwater by volume in three of the four tests. Toxicity was observed in Test No. 3; however, the 7-d LC50 could not be calculated because <50% mortality occurred after 7 d of exposure. The NOECs and LOECs in Test Nos. 1 and 2 could not be determined because significant reductions ( $\alpha = 0.05$ ) in neonate production occurred down to 32% and 18% groundwater by volume, respectively, which were the lowest concentrations used in the study (Appendix 20, Table A20-3 and Appendix 22, Table A22-3). The NOECs and LOECs in Test Nos. 3 and 4 were both 10% and 18%, respectively. The NOECs and LOECs were the same in Test Nos. 3 and 4 in both raw and buffered groundwater.

#### 5.1.2.3 Fathead Minnow

The 7-d LC50s, NOECs, and LOECs for the fathead minnow exposed to groundwater at pH 4 and 7 are summarized in Table 2. The test data and statistical analyses for Test Nos. 1-4 are given in Appendices 27-34. The groundwater at pH 4 was toxic in all tests. The short-term chronic 7-d LC50s at pH 4 ranged from 22-62% groundwater by volume. The NOECs at pH 4 ranged from 10-32% groundwater by volume while the LOECs ranged from 18-56% groundwater by volume in the four tests. The NOEC and LOEC endpoints at pH 4 were a reduction in growth for Test Nos. 1 and 2 and an increase in mortality in Test Nos. 3 and 4.

The groundwater was less toxic when buffered to pH 7 (Table 2). With regard to the 7-d LC50s at pH 7, no statistically significant ( $\alpha = 0.05$ ) mortality occurred in three of the four tests. Some mortality was observed in Test No. 2; however, a 7-d LC50 could not be calculated because <50% mortality occurred in 7 d of exposure. A significant reduction ( $\alpha = 0.05$ ) in growth occurred in Test No. 1 while a significant increase in mortality occurred in Test No. 2. The NOECs for Test Nos. 1 and 2 were 56% groundwater by volume, while the LOECs were 100% groundwater by volume. No NOECs or LOECs were obtained in the third and fourth tests because statistically significant ( $\alpha = 0.05$ ) increases in mortality or reductions in growth did not occur.

The chronic toxicity observed for the cladoceran and fathead minnow may be related to several heavy metals and at least one organic present in the groundwater (Table 3). As discussed below in Section 5.1.6.1, cadmium, nickel, and zinc concentrations in the groundwater are equal to or exceed the EPA freshwater chronic numerical water quality criteria of 1.1, 160, and 110  $\mu\text{g/L}$

(hardness dependent criteria; 100 mg/L as CaCO<sub>3</sub> used), respectively (U.S. EPA, 1980a; 1984a; 1987). None of the priority pollutant organics found in the groundwater currently have numerical water quality criteria values because insufficient data exist to develop criteria (Potts, 1994). However, 1,1,2,2-tetrachlorethane concentrations found in the groundwater exceed the EPA freshwater chronic LOEC (U.S. EPA, 1980b). Thus, it is likely that the chronic toxicity observed in the cladoceran and fathead minnow tests is a combination of metals and organics.

In contrast to the general reduction in acute toxicity when the rotifer and fathead minnow were tested in buffered groundwater, the chronic toxicity NOECs and LOECs values for the cladoceran were the same at pH 4 and 7 (Table 2). Thus, the suggestion above that toxicity attributable to heavy metals is reduced at the higher pH does not appear to be valid for the cladoceran in the chronic tests. The reason for this observation is not clear.

### 5.1.3 Genotoxicity Tests

#### 5.1.3.1 Gene Mutation Assay

The results of the Ames mutagenicity assays are summarized in Table 2. Both unconcentrated and concentrated (10X) groundwater Ames assays were conducted on 10% groundwater by volume, 1% groundwater by volume, and control water in Test Nos. 1 and 2; 100% groundwater, 10% groundwater by volume, and control water were assayed in Test Nos. 3 and 4. The reference for each study data report is given in Appendix 36 so that a copy can be obtained if further information is desired; the actual data reports were not included in the Appendix because of the excessive length of each report.

All of the unconcentrated and concentrated (10X) 100% groundwater, 10% groundwater by volume, 1% groundwater by volume, and diluent water assays were found to be non-mutagenic (negative) with tester strains TA98 and TA100 in both the presence and absence of an exogenous metabolic activation system of mammalian microsomal enzymes derived from Aroclor-induced rat liver (S9 mix). One deviation from the above results was found in the unconcentrated APG-EA diluent water in Test No. 1. With tester strain TA98 in the absence of S9 mix, the response was evaluated as marginal in two trials due to the presence of 1 dose with an MR  $\geq$  1.5 which was not accompanied by a dose response.

#### 5.1.3.2 Sister Chromatid Exchange Assay

The sister chromatid exchange (SCE) assay was performed once on concentrated samples ( $\approx$ 50,000X) of 100% groundwater, 10% groundwater by volume, APG-EA diluent water, and once on an unconcentrated 100% groundwater sample (Table 2). The actual

data reports were not included in the Appendix of this report because of their excessive length. The reference for each study report is given in Appendix 37.

The concentrated extract of 100% groundwater was considered positive for inducing sister chromatid exchange in Chinese hamster ovary cells under the nonactivation conditions of the study and weakly positive under the activation (exogenous metabolic activation system of mammalian microsomal enzymes derived from Aroclor-induced rat liver S9 mix) conditions of the study (Table 2). The unconcentrated sample of 100% groundwater was considered negative for inducing sister chromatid exchange in Chinese hamster ovary cells under the activation and nonactivation conditions of the assay. The concentrated extracts of the 10% groundwater by volume and APG-EA diluent water were also considered negative for inducing sister chromatid exchange in Chinese hamster ovary cells under the activation and nonactivation conditions of the assay.

A positive response was found for 100% groundwater in the SCE assay when the groundwater sample was concentrated  $\approx 50,000X$ . The SCE assay was negative for unconcentrated 100% groundwater. It is not clear that the SCE positive response in the 50,000X concentrated sample is important to aquatic organisms. As discussed below in Section 5.2, the potential for the heavy metals and aliphatic organics present in the groundwater to bioaccumulate is  $<100$ -fold because the  $\log K_{ow}$ s of the materials are  $\leq 3$ . It is clear that no chemical or physical process in the Bush River could cause a 50,000X increase in the concentration of the materials in the near-field of the groundwater discharge. Thus, organisms in the immediate vicinity of the groundwater discharge would never be exposed to a 50,000X increase in the contaminants.

#### 5.1.4 Developmental Toxicity Test

The 4-d LC50, 4-d EC50 (malformations), NOEC, and LOEC results for the FETAX assays conducted in groundwater at pH 4 and 7 are summarized in Table 2. The test data, statistical analyses, and types and numbers of malformed embryos that occurred after 96 h of exposure for Test Nos. 1-4 are given in Appendices 38-45. Little embryo lethality occurred in the groundwater at pH 4 or 7 (Table 2). The raw groundwater was not toxic to the embryos at pH 4 in the first three tests. Some toxicity occurred in Test No. 4; however, a LC50 could not be calculated because  $<50\%$  mortality occurred. The buffered groundwater was not toxic in two of the four test. Some mortality occurred in Test Nos. 2 and 4; however, a LC50 could not be calculated.

Significant ( $\alpha = 0.05$ ) embryo malformations occurred in the raw and buffered groundwater in all assays. A 96-h EC50

(malformations) of 89% groundwater by volume was obtained in the second test at pH 4; 96-h EC50s could not be calculated for any of the other tests. The NOECs and LOECs for the four groundwater tests at pH 4 were 10 and 18% groundwater by volume, respectively, in the first three tests and 32 and 56% groundwater by volume in Test No. 4. The NOECs and LOECs for the four groundwater tests at pH 7 were all 18 and 32% groundwater by volume, respectively. With the exception of the fourth test, the buffered groundwater was less toxic than the raw groundwater. For some unexplainable reason, the raw groundwater was less toxic than the buffered groundwater in Test No. 4.

The types of malformed embryos (as described by Bantle et al., 1991) after 96 h of exposure in raw groundwater were primarily coiled guts, multiple edema, and abdominal edema (see last table in each of Appendices 38-45). Severe, notochordal and facial malformations were also observed in <10% of the total malformations. Fewer malformations were observed in the buffered groundwater tests; however, the same types of malformations that occurred in the raw groundwater were observed in the buffered groundwater assays (primarily coiled guts, multiple and abdominal edema with <10% severe, notochord, and facial). The incidences of malformations were greater at the higher test concentrations in both the raw and buffered groundwater.

The developmental toxicity found in the FETAX assays is most likely related to the heavy metals present in the groundwater. Several heavy metals, including copper, cadmium, and zinc, have been shown to cause developmental problems in lower vertebrate aquatic organisms (Weis and Weis, 1989). Dawson et al. (1985) found that mixtures of heavy metals (copper, cadmium, lead, and zinc) from acidic mine sources caused teratogenic effects and mortality when evaluated by FETAX. When the pH was adjusted from lows which ranged from 3.2 to 5.9 to pH 7, toxicity and teratogenicity decreased. The same response occurred in the present study with the exception of Test No. 4 in which the raw groundwater was less toxic than the buffered groundwater. The possible role of the organics in the groundwater is not clear since FETAX data do not exist for the individual materials (Bantle, 1994).

#### 5.1.5 Chronic Histopathology and Growth Test

The Japanese medaka growth and histopathology results at 6 and 9 months of exposure to 10% groundwater by volume, 1% groundwater by volume, and diluent water are briefly summarized in Table 2. The wet weight and standard length raw data, means, and standard deviations of the means for each replicate tank in each treatment at 6 and 9 months are given in Appendix 46, Tables A46-1 and A46-3, respectively. The statistical analyses of the growth data at 6 and 9 months are given in Appendix 46, Tables A46-2 and A46-4.

No significant difference ( $\alpha = 0.05$ ) in wet weight or standard length was found between treatments after 6 and 9 months of exposure. With regard to the 9-month length data only, a statistically significant difference ( $\alpha = 0.003$ ) in standard length was found using the nonparametric Kruskal Wallis test (Appendix 46, Table A46-4). However, when Dunn's multiple comparison test was used to enumerate the difference between the control and each experimental treatment, no statistically significant difference ( $\alpha = 0.05$ ) was found. Standard length was judged not to be affected by a 9-month exposure to the groundwater because 1) Dunn's test could not discern any statistical difference ( $\alpha = 0.05$ ) between groups and 2) the numerical differences between mean lengths in the study groups were quite small. For example, the mean standard lengths of the four replicates combined at each treatment were 32.0, 31.8, and 32.5 mm respectively, for the control, 1% groundwater by volume, and 10% groundwater by volume groups.

The cumulative mortality of Japanese medaka during the 9-month study is shown graphically in Figure 3. Percent cumulative mortality is given in Figure 4. Cumulative percent mortality at 6 months for the controls, fish exposed to 1% groundwater by volume, and 10% groundwater by volume was 4.5, 2.5, and 2.1%, respectively. Cumulative percent mortality at 9 months for the controls, fish exposed to 1% groundwater by volume, and 10% groundwater by volume was 22.1, 11.7, and 7.2%, respectively. To the authors knowledge, there are no test mortality acceptability criteria for a 9-month test. If one uses the mortality acceptability criteria for early life stage (ELS) toxicity tests which run for 1-2 months after hatch or fry swim-up, the mortality observed in this study falls within ELS acceptability criteria (Goodman, 1986). For example, the ELS test acceptability criteria for all eight freshwater species listed in the draft ASTM standard guide (Japanese medaka are not include in the guide) run from 60-75% (Goodman, 1986). That is, for a test to be acceptable, 60-75% of the control organisms must be alive at the end of the study depending on the species being studied. Excluding fish sacrificed at 6 months, 77.9% of the control Japanese medaka were living at the end of the 9-month period.

The histopathological findings for the 6- and 9-month exposures are described in detail in the pathology report by Experimental Pathology Laboratories, Inc. (1994). A summary of the findings is given in Appendix 47. Briefly, the major conclusions of the histopathology study are as follows. After 6 months of exposure to control water, 1% groundwater by volume, and 10% groundwater by volume, liver neoplasia (hepatocellular adenoma and carcinoma) occurred only among Japanese medaka that had been previously initiated with DEN. Seven of 40 medaka were affected in the fish exposed to 10% groundwater by volume as compared to 2 of 40 among the controls and 1 of 40 Japanese medaka exposed to 1% groundwater by volume.



After 9 months of exposure, hepatocellular adenomas or carcinomas, single or multiple, occurred in DEN-initiated Japanese medaka that had been exposed to control water, 1% groundwater by volume, and 10% groundwater by volume. There were as many neoplasms among the controls (8 of 122) as among the 10% exposure group (8 of 144). There were two liver neoplasms (1 hepatocellular adenoma and 1 carcinoma) in Japanese medaka exposed to 10% groundwater by volume (no DEN exposure). Two additional liver neoplasms not related to hepatocytes occurred in the DEN 10% groundwater by volume group. One was a cholangioma and the other was a carcinoma, cell of origin unknown. In the DEN 1% groundwater by volume exposure groups there were five (5 of 144) hepatocellular neoplasms, all adenomas. At 9 months there was no dose-related response for liver neoplasia in Japanese medaka exposed to groundwater.

Other neoplasms that occurred sporadically among the various exposure groups at 6 and 9 months included lymphosarcoma, seminoma, thyroid follicular cell adenoma, thyroid follicular cell carcinoma, hemangioma of the gills, and a gallbladder papilloma.

Granulomatous inflammation of the subcutaneous tissue of the lower and/or upper jaw occurred in small numbers of male fish at 6 months. The same lesion occurred among Japanese medaka of all exposure groups at 9 months. The incidence was substantially greater among males than among females. For example, 144 males overall versus 17 females were diagnosed with granulomatous inflammation of the lower jaw. Granulomatous inflammation or granulomas occurred in a variety of additional tissues among all exposure groups. The reason for the higher incidence of these lesions in males versus females is not known. Trauma may be an initiating factor in the granulomatous lesions of the jaws, but the reason why the jaws of these fish should be traumatized is not known.

Granulomas in the heart, hematopoietic tissue, liver, and spleen occurred in the highest incidence in the controls and in the lowest incidence in Japanese medaka exposed to 10% groundwater by volume. The reasons for this lower incidence among fish exposed to 10% groundwater by volume as compared to the controls is not known.

The DEN-induced hepatic neoplasia found in this study have been observed by several investigators using the Japanese medaka as a model to evaluate carcinogenic potential of selected chemicals in aquatic organisms (for ex., Bunton, 1990; Lauren et al., 1990; Hinton et al., 1988). Protocols for studying DEN hepatocarcinogenicity vary but generally involve exposure to 10-100 mg/L DEN in ambient water for several days or weeks followed by several weeks for tumor development (Hinton et al., 1985). The DEN exposure period in this study was 48 h, which is

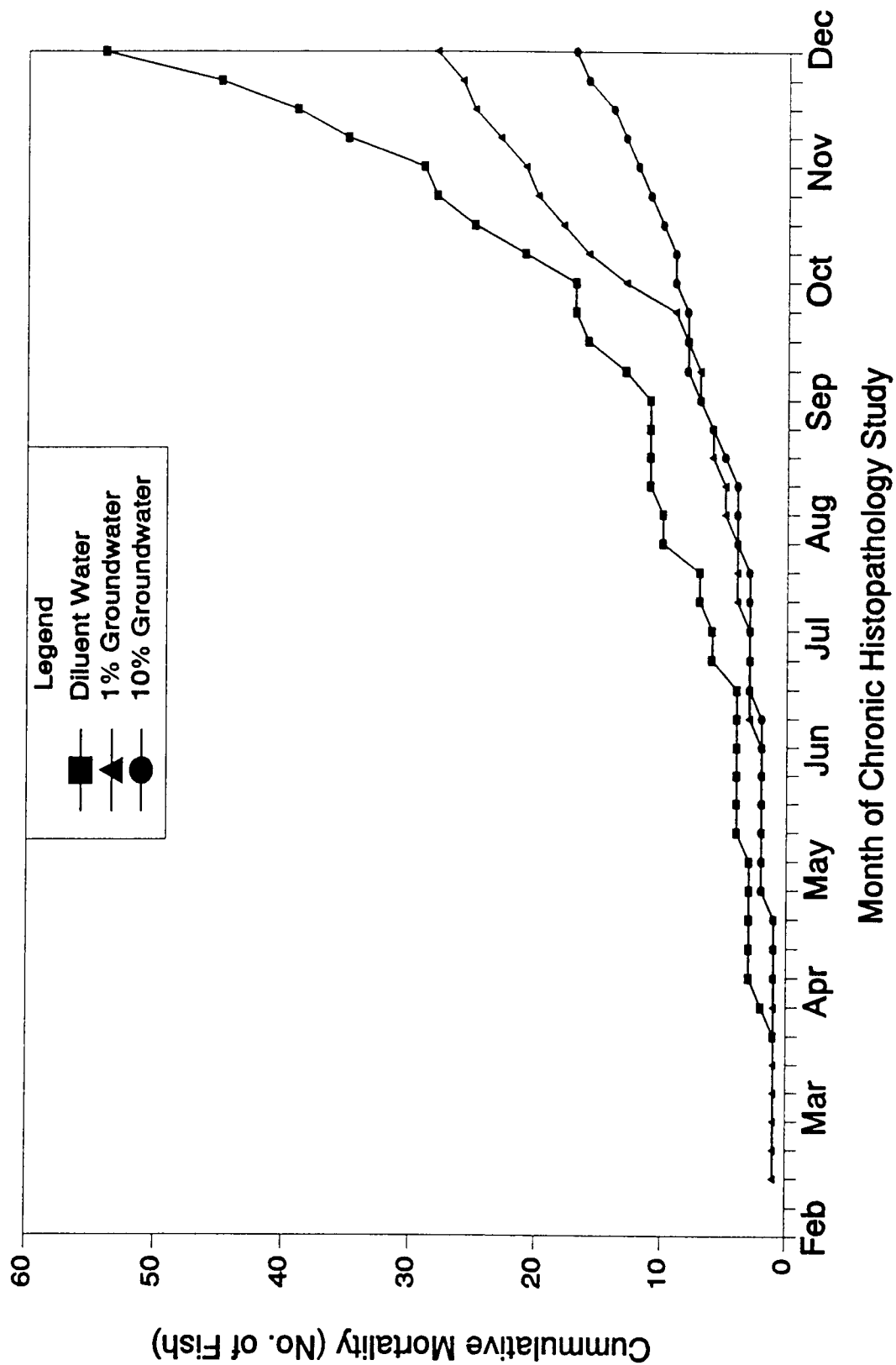


Figure 3. Cumulative mortality of Japanese medaka during the 9-month chronic histopathology exposure study.

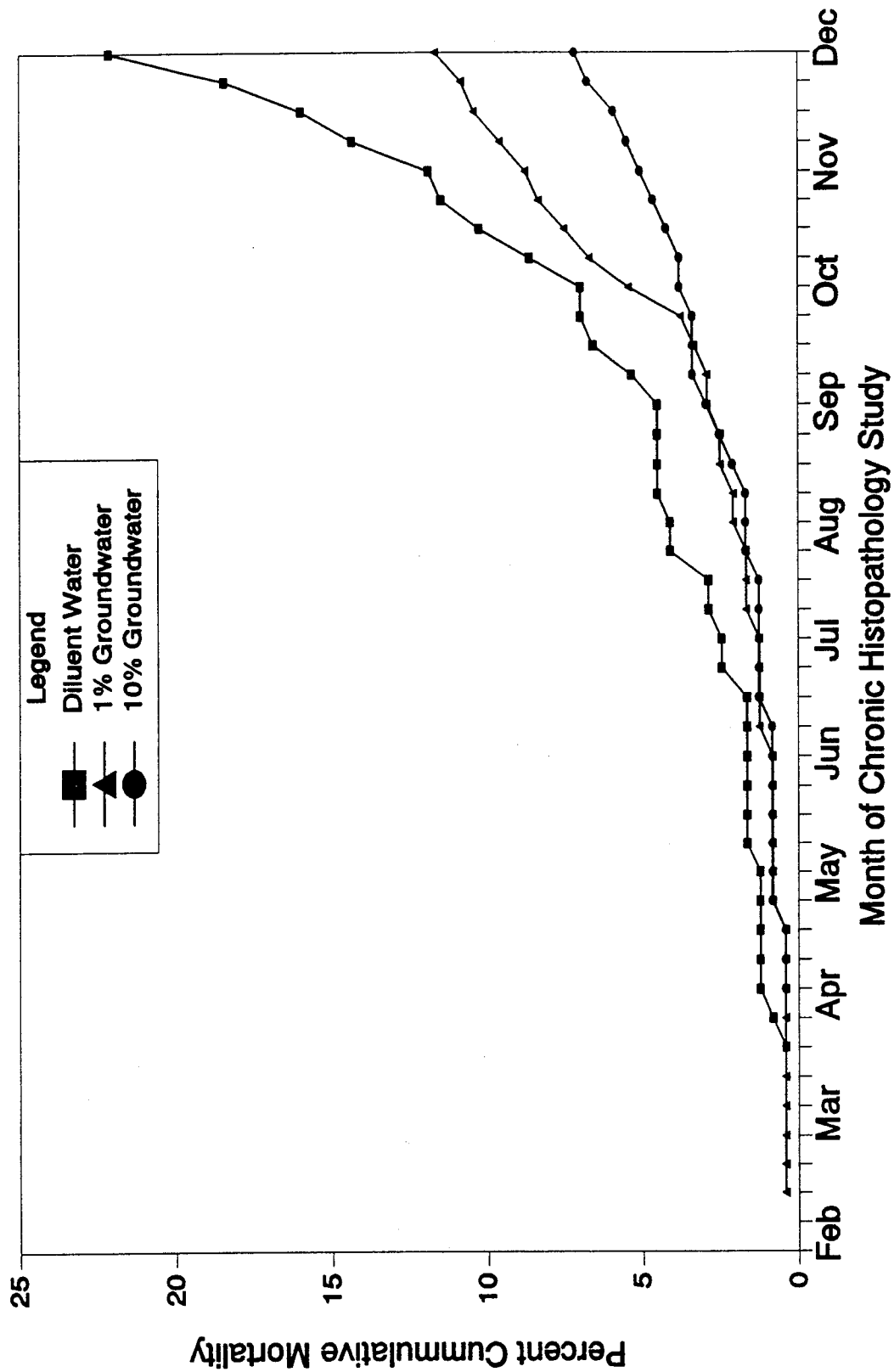


Figure 4. Percent cumulative mortality of Japanese medaka during the 9-month chronic histopathology exposure study.

substantially shorter than the exposure periods normally used by other investigators. Ichikawa and Takayama (1979) have shown that the length of exposure and length of grow-out can enhance hepatic neoplasia induced by DEN.

Little, if any, data are available on the potential carcinogenicity of heavy metals to the Japanese medaka (Hawkins, 1994). Similarly, short-chain halogenated hydrocarbons have received little study relative to other organic groups, e.g., nitroso compounds, polynuclear aromatic hydrocarbons, and aromatic amines (Walker et al., 1985). 1,1,2,2-Tetrachloroethane was not found to be carcinogenic to Japanese medaka exposed to concentrations up to 14 mg/L in a recent study by Hawkins (1991).

The four bimonthly comprehensive chemical analyses for the 9-month study are given in Appendix 48 (see Section 5.1.6.1). The general water quality data, means, and standard deviations of the means for each replicate tank in each treatment for the 9-month study are given in Appendix 49 (see Section 5.1.6.2).

#### 5.1.6 Chemical Analyses

##### 5.1.6.1 Comprehensive Chemical Analyses

A summary of the raw groundwater general water quality, heavy metals, and volatile organics measured in the samples of the four bimonthly comprehensive chemical analyses is given in Table 3. The range of the lowest and highest concentrations of the four analyses is presented. The comprehensive results of each bimonthly chemical analysis, including the values for 100% groundwater, 10% groundwater by volume, 1% groundwater by volume, and diluent water are given in Appendix 48, Tables A48-1, A48-2, A48-3, and A48-4 for Test Nos. 1, 2, 3, and 4, respectively. The tables in Appendix 48 include the test method and detection limit for each chemical. In contrast to Table 3, which contains only the range of materials actually measured in the samples, all materials measured and quantified as well as materials not detected during analysis are included in Appendix 48.

No compounds in the following groups were detected at EPA's quantitation limits for groundwater: 1) acid or base/neutral compounds; 2) pesticides; 3) herbicides; or 4) organo-phosphorus pesticides. The following munitions were not detected at a quantitation limit of 50  $\mu\text{g/L}$ : 1) octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX); 2) hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX); 3) 1,3,5-trinitrobenzene (TNB); 4) N,2,4,6-tetranitro-N-methylaniline (tetryl); 5) trinitrotoluene (TNT); 6) 2,4-dinitrotoluene (2,4-DNT); or 7) 2,6-dinitro-toluene (2,6-DNT).

The general water chemistry parameters of the groundwater summarized in Table 3 show that the groundwater is a moderately

hard water (hardness = 170-230 mg/L as  $\text{CaCO}_3$ ). The pH of 3.9-4.1 is low relative to that which occurs in most surface waters. Some surface waters high in tannic acid or those waters impacted by acid rain may also have pH values in the same range (Baker et al., 1990). Ammonia-nitrogen was <0.1 mg/L in all samples; thus, nonionized ammonia would not be expected to play a role in toxicity (Thurston et al., 1979).

Several EPA priority pollutant heavy metals were found in the groundwater (Table 3). The concentrations of cadmium, copper, nickel, and zinc exceeded one or more of EPA's numerical water quality criteria for the specific metal. Cadmium, nickel, and zinc concentrations were equal to or exceeded the EPA freshwater chronic numerical water quality criteria of 1.1, 160, and 110  $\mu\text{g/L}$  (hardness dependent criteria; 100 mg/L as  $\text{CaCO}_3$  used), respectively (U.S. EPA, 1980a; 1984a; 1987). Zinc also exceeded the freshwater acute criteria of 120  $\mu\text{g/L}$  (hardness dependent criteria; 100 mg/L as  $\text{CaCO}_3$  used). Copper exceeded EPA's saltwater acute criterion of 2.9  $\mu\text{g/L}$  (U.S. EPA, 1984b); a chronic saltwater copper criterion does not exist (Potts, 1994). Aluminum was also present at high concentrations in the groundwater; however, EPA has not established numerical water quality criteria for the metal in freshwater or saltwater under acute or chronic exposure conditions (Potts, 1994).

A number of chlorinated aliphatic compounds were found in the groundwater (Table 3). Several of the organics were EPA priority pollutants. None of the priority pollutant organics found in the groundwater currently have numerical water quality criteria values because insufficient data exist to develop criteria (Potts, 1994). EPA does give the LOEC for several of the compounds where criteria are not available. 1,1,2,2-Tetrachlorethane concentrations found in the groundwater exceed the EPA freshwater chronic LOEC of 2,400  $\mu\text{g/L}$ ; no freshwater acute LOEC is given by EPA (U.S. EPA, 1980b). None of the 10 volatile organics found in the groundwater have octanol water partition coefficients ( $\log k_{ow}$  or  $\log P$ ) >3 (Table 4). Thus, bioaccumulation is not a potential toxicological problem (see Section 5.2.1).

#### 5.1.6.2 Routine Water Quality Analyses

The raw data, mean, and standard deviation of the mean for each exposure tank in the chronic histopathology study are given in Appendix 49. The methods for determining the routine water quality are given in Appendix 50. Although some of the water quality parameters varied as a function of the three treatments, water quality within a given treatment was quite consistent over the 9-month study. The continuous temperature measurement recorded from Tank No. 3 during the 9-month study verified the constant temperature conditions which were measured daily in each exposure tank.

TABLE 4. LOG OCTANOL WATER PARTITION COEFFICIENTS OF THE ORGANIC CONTAMINANTS DETECTED IN WELL CC-33B

Contaminant	Log $K_{ow}$
Chlorobenzene	2.8 <sup>a</sup>
Chloroform	1.9 <sup>b</sup>
1,1,2-Trichloroethane	2.2 <sup>b</sup>
1,1,1,2-Tetrachloroethane	3.0 <sup>c</sup>
1,1,2,2-Tetrachloroethane	2.4 <sup>b</sup>
1,1-Dichlorethene	2.1 <sup>a</sup>
cis-1,2-Dichloroethene	1.8 <sup>d</sup>
Trichloroethene	2.4 <sup>b</sup>
Tetrachloroethene	2.9 <sup>b</sup>
Vinyl chloride	1.4 <sup>c</sup>

<sup>a</sup> Value taken from Howard (1989).

<sup>b</sup> Value taken from U.S. EPA (1991b).

<sup>c</sup> Value taken from Mackay et al. (1993).

<sup>d</sup> Value taken from Howard (1990).

## 5.2 Hazard Assessment Evaluation

### 5.2.1 Toxicity

As discussed in Section 4.2, the ASTM guide recommends a phased hazard iteration process (ASTM, 1992b). Phase I (low-cost), Phase II (medium-cost), and Phase III (high-cost) toxicological data collection/iterations were all conducted simultaneously during the biomonitoring evaluation studies. Thus, the decision that normally would be made at the end of each phase concerning whether or not the potential hazard should be assessed as either 1) minimal, 2) potentially excessive, or 3) uncertain was not made until the end of the biomonitoring study when all of the toxicological studies were complete.

One important decision regarding bioaccumulation in aquatic organisms was made at the end of Phase I. The hazardous heavy metals present in the groundwater (Table 3) do not bioaccumulate to any degree in their metallic form in tissues (Williamson et al., 1993). Some heavy metals will bioaccumulate in the shells of benthic organisms; however, bioaccumulation in the shells is not believed to interfere with the normal physiological function of the organisms. With regard to the halogenated organics present in the groundwater, the log  $K_{ow}$ s (log P) of all the organics are  $\leq 3$  (Table 4). Bioaccumulation of a material up to 100-fold above background (bioconcentration factor or BCF = 100) can occur when the log  $K_{ow}$ s = 3 (U.S. EPA, 1991c). Thus,

bioaccumulation was judged not to be an issue in the hazard assessment.

Toxicity was detected at various groundwater concentrations by all of the biomonitoring systems at pH 4 with the exception of two assays (Section 5.1). The Ames test for mutagenicity was negative in all cases including 100% groundwater as was the 9-month Japanese medaka chronic growth and histopathological test up to 10% groundwater by volume. A positive response was found in 100% groundwater in the SCE assay when the groundwater sample was concentrated  $\approx 50,000\times$ ; the SCE assay was negative in 100% groundwater which was not concentrated. As discussed in Section 5.1.3.2, the SCE findings for concentrated 100% groundwater were not considered to be important to aquatic organisms in the near-field of the groundwater discharge.

The lowest concentration of groundwater that caused no observable adverse effect at pH 4, in the test systems in which the NOEC value could be determined, was 10% groundwater by volume. A NOEC of 10% groundwater by volume occurred in 3 out of 4 tests in both the cladoceran and FETAX assays; it occurred once in the fathead minnow test. The NOEC concentration was higher at pH 7 in both the fathead minnow and FETAX assays. The 10% groundwater by volume NOEC for cladoceran at pH 4, however, did not change when the organism was exposed to buffered groundwater at pH 7.

Maximum acceptable toxicant concentrations (MATC) are normally required for chronic toxicity estimates in a hazard assessment (ASTM, 1992b). The MATC is the highest concentration of a material that would have no statistically significant observed effect on the survival, growth, or reproduction of a test species during continuous exposure throughout a life-cycle or partial life cycle test. The short-term chronic tests with the green alga and cladoceran can be used to estimate the MATC for a plant and invertebrate (Weber et al., 1989). The green algal test is a multi-generation assay. The cladoceran test is a partial life cycle test. The MATC for the alga and cladoceran would be 18 and 10% groundwater by volume, respectively.

One can estimate chronic toxicity by calculating the acute-to-chronic ratio (ACR) which is simply the ratio of the LC50 to the NOEC (U.S. EPA, 1991a). The ACRs for the fathead minnow at pH 4 ranged from 1.4 to 2.0 in the four bimonthly tests. Thus, chronic toxicity of the groundwater to the fathead minnow would be estimated to be  $\approx 2$ -fold greater than the acute toxicity. The estimated MATC of the groundwater to the fathead minnow would be  $\approx 11\%$  groundwater by volume. Although the 9-month Japanese medaka growth test is not a partial life cycle test by definition, the groundwater had no effect on Japanese medaka growth or chronic histopathology at 10% groundwater by volume after a 9-month exposure.

The estimated MATCs for the alga, invertebrate, and fish in the biomonitoring study suggest that the groundwater would not be harmful at a concentration of 10% groundwater by volume. Likewise, no genotoxicity, developmental toxicity, or chronic histopathology occurred at 10% groundwater by volume. Thus, the biomonitoring data suggest that chronic toxicity may not occur in the receiving stream at a dilution of 10:1. Chronic toxicity, however, would be predicted to occur in the Bush River if the groundwater entered the receiving stream at the concentrations which occur in well CC-33B.

In conclusion, if all of the conservative assumptions presented in Section 4.2 concerning the groundwater are assumed to occur (e.g., homogeneously mixed heavy metals and DNAPLs, no chemical or biotic transformations of the materials, large release volumes through the sediments to the Bush River, etc.), the groundwater would be considered a potentially excessive hazardous material to the benthic biota of the Bush River (ASTM, 1992b). The hazard to water column aquatic organisms would rapidly dissipate as the materials mixed in the receiving stream. We argue below that even if all of the conservative assumptions in Section 4.2 for the groundwater were used, that potential water quality impacts would be minimal if a mixing zone was granted by the State of Maryland which allows for local exceedences of water quality standards. The State of Maryland allows on a case-by-case basis a mixing zone where acute and chronic water quality criteria may be exceeded (see Section 5.2.4). Standards for a mixing zone for acute and chronic sediment quality do not currently exist.

#### 5.2.2 Near-field Dilution in the Bush River

The results of the ULINE near-field model study are given in Najarian Associates, Inc. (1994). A copy of the Najarian report is included in this report as Appendix 51. The ULINE near-field model results indicate that a near-field dilution ratio of 159:1 is appropriate for application of the Maryland Department of the Environment's (MDE) acute aquatic life toxicity criteria. The model shows that a far-field dilution factor of 1,006:1 is appropriate for application of chronic toxicity criteria. A dilution factor of 159:1 means that when 1 part of Beach Point groundwater is diluted in 159 parts of Bush River water, MDE's acute criteria are met at the edge of the acute mixing zone. MDE's acute and chronic aquatic life criteria are the same as those derived by EPA. Note that far-field flushing parameters are not included in the ULINE near-field model. When near-field dilution is corrected for the influence of far-field flushing, the resulting total near-field dilution ratios will decrease (see below).

A model sensitivity analysis was performed to evaluate the effects of various parameter variations on the near-field ULINE



model output. The results of the model sensitivity analysis are given in Figures 2-6 of the Najarian report in Appendix 51. The sensitivity analysis showed that variations in groundwater discharge will change the dilution ratios. A groundwater discharge rate of 1,176 m<sup>3</sup>/d (Section 4.2.3) gives a dilution ratio of 159. A higher discharge rate of 2,160 m<sup>3</sup>/d, for example, will decrease the near-field ratio to 88. The length of the groundwater discharge in the Bush River affects the dilution ratio. The length of the discharge used in the model was assumed to be 448 m (entire length of Beach Point Peninsular). However, a more conservative estimate of approximately half the length of the peninsular (i.e., 224 m) gives a near-field dilution ratio of 81; a length of approximately one third gives a factor of 54. The sensitivity analysis also showed that dilution ratios are somewhat dependent upon the assumed discharge depth, are sensitive to ambient current speed, and relatively insensitive to salinity.

The total near-field dilutions (near-field dilution corrected for the influence of far-field dilution) for MDE's acute toxicity criteria under Spring and Fall conditions were 42 and 43, respectively. The total near-field dilutions for chronic toxicity criteria were 168 and 185, respectively, under Spring and Fall conditions (Appendix 51). (As discussed in Section 5.2.1 above, no acute or chronic toxicity occurred in any of the biomonitoring systems at a dilution of 10). Using the above total near-field dilution factors, near-field concentrations can be estimated for toxicants of interest. The estimate is obtained by dividing the groundwater contaminant concentration by the dilution factor. For example, using the Spring dilution factor of 42, a pollutant concentration of 42 µg/L would be diluted to 1 µg/L within the near-field mixing zone limit of the Beach Point discharge in the Bush River. Using this relationship, the near-field concentrations for all the groundwater contaminants can be calculated.

The computed acute and chronic dilutions for the highest concentration of each heavy metal and aliphatic organic measured in well CC-33B (Table 3) are given in Table 5. The computed dilutions for both the acute and chronic values were determined using the Spring acute and chronic dilution factors (i.e., 42 and 168). An examination of the results in Table 5 show that the expected near-field impacts would be near or below the analytical method detection limit for most of the contaminants. For the heavy metals and organics that would be discharged in the Beach Point groundwater under the worst-case assumptions of this hazard assessment, the analysis suggests that on-site contamination will not produce any discernable adverse effect on the water quality of the Bush River.

TABLE 5. COMPUTED DILUTIONS OF THE GROUNDWATER METALS AND ORGANICS IN THE BUSH RIVER<sup>a</sup>

Contaminant	Maximum Groundwater Concentration	<u>Bush River Concentration</u>	
		Acute <sup>b</sup>	Chronic <sup>c</sup>
<u>Heavy Metals</u>			
Aluminum	1,500	35.71	8.93
Arsenic	7	0.17	0.04
Boron	70	1.67	0.42
Cadmium	1.4	0.03	0.01
Cobalt	110	0.19	0.05
Copper	8	0.19	0.05
Nickel	180	4.29	1.07
Zinc	310	7.38	1.85
<u>Volatile Organics</u>			
Chlorobenzene	2	0.05	0.01
Chloroform	12	0.29	0.01
1,1,2-Trichloroethane	110	2.62	0.65
1,1,1,2-Tetrachloroethane	3	0.07	0.02
1,1,2,2-Tetrachloroethane	17,000	404.76	101.19
1,1-Dichlorethene	1	0.02	0.006
cis-1,2-Dichloroethene	640	15.24	3.81
Trichloroethene	1,600	38.10	9.52
Tetrachloroethene	90	2.14	0.54
Vinyl chloride	2	0.05	0.01

<sup>a</sup> All heavy metal and volatile organic concentrations are given as  $\mu\text{g/L}$ .

<sup>b</sup> Based on the maximum concentration measured during the four bimonthly chemical analyses and dilution ratio of 42:1 (see Section 5.2.2).

<sup>c</sup> Based on the maximum concentration measured during the four bimonthly chemical analyses and dilution ratio of 168:1 (see Section 5.2.2).

### 5.2.3 Mixing Zone Consideration

#### 5.2.3.1 Mixing Zone Regulations

The State of Maryland allows for a mixing zone on a case-by-case basis. The State regulations regarding mixing zones are discussed in detail in the report by Najarian Associates, Inc. (1994). Briefly, as discussed in the Najarian report, a mixing

zone is defined by the State of Maryland (COMAR 26.08.01.01B) as "an area contiguous to a discharge where surface water quality or groundwater quality does not have to meet: (a) all water quality criteria, or (b) all requirements otherwise applicable to the natural water." That is, pollutant concentrations within the mixing zone may exceed the specified water quality standards within a localized vicinity of the outfall. The dimensions of the zone are normally comparable to those associated with the initial dilution process (e.g., 10-100 m). Thus, aquatic organisms would only be exposed to concentrations exceeding the specified criteria for a brief period during a transit of the mixing zone. COMAR 26.08.02.05A further states that mixing zones may be allowed only if they meet a number of requirements which ensure that no interference to aquatic ecosystem uses occurs outside the mixing zone (the list of requirements are given in Najarian Associates, Inc., 1994).

Four types of numerical toxic substance criteria are promulgated by the MDE: 1) human health criteria through ingestion of public water supplies; 2) the wholesomeness of fish for human consumption; 3) fresh, estuarine, and salt water aquatic life criteria from acute toxicity impacts; and 4) fresh, estuarine, and salt water aquatic life criteria from chronic toxicity impacts. For the purpose of applying numerical toxic substance criteria, the Bush River Area (Sub-Basin 02-13-07) is classified by MDE as "freshwater" (COMAR 26.08.02.03-1B) and as "Use II" (shellfish harvesting waters). The toxic substances criteria for both ambient surface waters ("freshwater") and human health ("fish consumption") for the pollutants in well CC-33B at Beach Point are given in Table 6. Toxic criteria related to drinking water do not apply to shellfish harvesting waters.

The following regulations (COMAR 26.08.02.05D) pertain to the application of toxic substance chronic criteria for the protection of aquatic life. First, in terms of size, the Regulatory Mixing Zone (i.e., the mixing zone in which the chronic criteria are applied) may not exceed 10 percent of the cross-sectional area of the receiving waters. Also, the chronic criteria are applied under flow conditions determined from site-specific data for the mean tide level, average tidal velocity, and, when appropriate, the design stream flow. Based on MDE's discretion, a plume dilution study may also be required for the application of these criteria. In accordance with COMAR 26.08.02.06(a), conditions pertinent to the application of toxic substance chronic criteria are also relevant to the application of toxic substance human health criteria.

The following regulations (COMAR 26.08.02.05C) pertain to the application of toxic substance acute criteria for the protection of aquatic life. Such acute criteria (for low velocity dischargers) must be met within a short distance from the outfall using the most restrictive of the following:

TABLE 6. APPLICABLE TOXIC SUBSTANCES CRITERIA FOR THE BUSH RIVER AND A COMPARISON OF PROJECTED NEAR-FIELD GROUNDWATER CONCENTRATIONS<sup>a</sup>

Constituent	Acute Conditions		Chronic Conditions		
	Aquatic Life Criteria	Near-Field Conc.	Aquatic Life Criteria	Near-Field Conc.	Human Health Fish Consumption
<u>Heavy Metals</u>					
Aluminum	b	35.71	b	8.93	c
Arsenic (III)	360 <sup>d</sup>	0.17 ( tot)	190 <sup>d</sup>	0.04 (tot)	c
Cadmium	3.9 <sup>d</sup>	0.03	1.1 <sup>d</sup>	0.01	c
Copper	18 <sup>d</sup>	0.19	12 <sup>d</sup>	0.05	c
Nickel	1,400 <sup>d</sup>	4.29	160 <sup>d</sup>	1.07	100
Zinc	120 <sup>d</sup>	7.38	110 <sup>d</sup>	1.85	c
<u>Volatile Organics</u>					
Chlorobenzene	e	0.05	e	0.01	c
Chloroform	28,000 <sup>f</sup>	0.29	1,240 <sup>f</sup>	0.01	c
1,1,2-Trichloroethane	e	2.62	9,400 <sup>f</sup>	0.65	c
1,1,1,2-Tetrachloroethane	e	0.07	e	0.02	c
1,1,2,2-Tetrachloroethane	e	404.76	2,400 <sup>f</sup>	101.19	c
1,1-Dichloroethene	e	0.02	e	0.006	c
cis-1,2-Dichloroethene	e	15.24	e	3.81	c
Trichloroethene	e	38.10	e	9.52	807
Tetrachloroethene	e	2.14	e	0.54	c
Vinyl chloride	e	0.05	e	0.01	c

<sup>a</sup> All heavy metal and volatile organic concentrations are given as  $\mu\text{g/L}$ .

<sup>a</sup> EPA acute and chronic aquatic life criteria are pH dependent; State of Maryland has no standard for aluminum.

<sup>b</sup> No State of Maryland criteria.

<sup>c</sup> Acute and chronic aquatic life criteria are hardness dependent (100 mg/L  $\text{CaCO}_3$  used).

<sup>d</sup> No State of Maryland or EPA criteria.

<sup>e</sup> No State of Maryland or EPA criteria. Value presented is EPA's LOEC.

- 1) Within 10 percent of the distance (in any spatial direction) from the discharge to the edge of the Regulatory Mixing Zone used for the application of the chronic criteria.
- 2) Within a distance of 50 times at the "discharge length scale" (i.e., 50 times the square root of the cross-sectional area of the discharge outlet).
- 3) Within a distance of 5 times the local water depth in any horizontal direction from the discharge outlet.

Thus, the region where the acute criteria are applied, sometimes called the "Toxic Dilution Zone", extends outward from the discharge to a distance no larger than any of the three lengths cited above. Moreover, the Toxic Dilution Zone must not occupy more than 5 percent of the cross-sectional area of the receiving waters. Finally, the acute criteria are applied under flow conditions determined from site-specific data for the mean low water elevation, the minimum daily averaged 1-h tidal velocity and, when appropriate, design stream flow conditions. Such tidal stages are deemed "critical" (minimum dilution) conditions.

#### 5.2.3.2 Site Applicability

The regulatory conditions relevant to mixing zones were developed for outfall diffusers. Their application to an area-wide groundwater discharge is somewhat uncertain due to the unknown extent of the area. It seems likely that the discharge area is confined within the Regulatory Mixing Zone, which for Beach Point, extends approximately 150 m ( $\approx 500$  ft) from the river bank. However, the extent of the Toxic Dilution Zone is more poorly defined because it partially depends on the configuration of the groundwater discharge. Thus, the applicability of the mixing zone concept must be further examined.

There are three approaches used for the assessment of toxic substance discharges in the United States (U.S. EPA, 1993b). The concept of a mixing zone provides an intermediate approach to the assessment of toxic pollutant impacts. The two other approaches generally in use are "end of pipe" and "fully mixed". The "end of pipe" approach allows for zero dilution; aquatic life criteria are applied directly to the discharge water quality. This simplified approach yields the most stringent results which, in turn, most ensures the protection of aquatic biota. However, as Najarian Associates, Inc. (1994) points out, it may lack a physical or biological basis in terms of receiving water impacts. Thus, its results are not considered to be defensible. It is effectively a non-technically based policy decision.

Conversely, the "fully mixed" (or far-field) approach considers the total volume of a receiving water segment to be

instantly available for the dilution of a discharge. This approach is generally far less stringent than the "end of pipe" approach. However, it may not adequately address biological impacts in the receiving water due to near-field conditions. The concept of mixing zones evolved to address these limitations. Mixing zones allow consideration of the initial dilution process. This approach also protects aquatic life by limiting the potential for exposure to elevated concentrations to minor portions of the waterway. Since only a portion of the available dilution is considered in this approach, mixing zones provide a much more stringent basis for regulation than the "fully mixed" approach.

In the application of the mixing zone concept to the Bush River, it was necessary to conceptualize the area-wide groundwater discharge from Beach Point as a line source (diffuser). Because of this approach, potential impacts could be assessed in a technically defensible manner. However, the approach had a side effect of concentrating the groundwater impact into a smaller area. That is, the approach minimized the available near-field dilution and projected higher receiving water concentrations than would actually occur. Thus, the mixing zone analysis produced an overly conservative result. In the near-field, actual receiving water concentrations would be less than those projected due to the more dispersed nature of the groundwater plume. In the near-field, projected and actual receiving water concentrations should be comparable. However, far-field concentrations would always be less than the near-field projections.

#### 5.2.3.3 Conformance with Aquatic Life Criteria

The anticipated near-field receiving water concentrations are compared in Table 6 with the water quality criteria for the contaminants in well CC-33B. As can be seen in Table 6, no exceedences of the criteria are projected. It is important to point out that no exceedences of the criteria are projected for groundwater discharge pollutants which were assumed to have the highest concentrations measured in well CC-33B. The assumption that the groundwater discharge would have concentrations as high as those in well CC-33B is very conservative.

There would be detectable concentrations of some of the chlorinated organics in the receiving stream if the contaminant distribution assumptions in Section 4.2.4 are used in the near-field projection. With the exception of trichloroethene for human health fish consumption, the State of Maryland has not implemented criteria for the remaining organics present in the groundwater.

#### 5.2.3.4 Re-evaluation of Hazard Assessment Assumptions as an Alternative to a Mixing Zone

It is argued above that the State of Maryland could consider a mixing zone for the discharge of Beach Point groundwater to the Bush River. The argument for a mixing zone, however, is based on the assumption that rather large volumes of groundwater with high concentrations of contaminants may enter the Bush River. As discussed in Sections 4.2.3 and 4.2.4, the volume of groundwater and the concentrations of contaminants in the groundwater that were assumed to occur in the near-field mixing zone were based on a number of very conservative assumptions. It is highly unlikely that the contaminant loads assumed in the near-field dilution model will ever occur in the Bush River. Thus, the assumptions that were used in the dilution model should be evaluated further before a decision is made to request a mixing zone. A refinement of the assumptions would reduce the volume of the discharge as well as the concentration of contaminants that may enter the receiving stream. Finally, the State may not consider a mixing zone for a groundwater discharge as a policy to reduce contaminant loading in the Bush River.

A better estimate of the discharge rate of the surficial aquifer is needed. Several of the conservative assumptions discussed in Section 4.2.3 concerning the discharge rate could be re-evaluated to obtain better estimates that could be used in the discharge rate calculation. The following could be examined: 1) Is the horizontal transport value  $V_{hor}$  of 0.27 m/d (0.89 ft/d), which was taken from one 25-h study in an intermediate depth well (CC-33B.1), representative of the entire aquifer? 2) Is the aquifer homogeneous? 3) Does isotropic flow occur throughout the aquifer? 4) Is the average saturated thickness of the aquifer 18.8 m (61.8 ft)? 5) Does the aquifer discharge over the entire length of Beach Point Peninsula fronting the Bush River?

The following assumptions concerning the concentrations of contaminants in the groundwater (Section 4.2.4) may be considered: 1) What is the extent of heavy metal retardation via adsorption onto solid surfaces or trapping by clays through ion exchange? 2) How important is the precipitation of metals when the pH shifts from 4 to neutrality as the groundwater moves through the sediments into the receiving stream? 3) How are the DNAPL concentrations changed as abiotic (chemical) and biotic (microbial) transformations occur? 4) The assumption was made that the heavy metals and residual DNAPLs were homogeneously mixed throughout the complete aquifer. The concentrations of the materials in the shallow and intermediate wells clearly show that this is not the case. Thus, better estimates of the distribution (concentration) of the materials in the aquifer are needed. This is particularly important for vertical flux estimates of the DNAPLs.

## SECTION 6

### CONCLUSIONS

#### 6.1 Biomonitoring Evaluation

Several EPA priority pollutant heavy metals were found in the groundwater. The concentrations of cadmium, copper, nickel, and zinc exceeded one or more of EPA's numerical water quality criteria for the specific metal. A number of chlorinated aliphatic compounds were also found in the groundwater, several of which are EPA priority pollutants. None of the priority pollutant organics found in the groundwater have EPA numerical water quality criteria values because insufficient data exist to develop criteria. 1,1,2,2-Tetrachlorethane concentrations found in the groundwater exceeded EPA's freshwater chronic LOEC value. None of the organics found in the groundwater have octanol water partition coefficients ( $\log K_{ow}$  or  $\log P$ )  $>3$ ; thus, bioaccumulation is not a potential toxicological problem.

Toxicity was detected at various groundwater concentrations by all biomonitoring systems at pH 4 with the exception of two assays. The Ames assay for mutagenicity was negative in all cases (1, 10, and 100% groundwater by volume). Japanese medaka growth was not affected by 9 months of exposure to 1 and 10% groundwater by volume in the chronic histopathology assay. No significant lesions were found in the Japanese medaka exposed to groundwater concentrations up to 10% groundwater by volume. A positive response was found for 100% groundwater in the SCE assay when the groundwater sample was concentrated  $\approx 50,000X$ . The SCE assay was negative for unconcentrated 100% groundwater. The positive SCE response in the 50,000X concentrated sample was judged not to be important to aquatic organisms in the vicinity of the groundwater discharge.

The lowest concentration of groundwater that caused no observable adverse effect at pH 4, in the test systems in which the NOEC value could be determined, was 10% groundwater by volume. A NOEC of 10% groundwater by volume occurred in 3 out of 4 tests in both the cladoceran and FETAX assays; it occurred once in the fathead minnow test. The NOEC concentration was higher at pH 7 in both the fathead minnow and FETAX assays. The 10% groundwater by volume NOEC for cladoceran at pH 4, however, did not change when the organism was exposed to buffered groundwater at pH 7.

The data for the alga, invertebrate, and fish in the biomonitoring study suggest that the groundwater would not be harmful at a concentration of 10% groundwater by volume. Likewise, no genotoxicity, developmental toxicity, or chronic histopathology occurred at 10% groundwater by volume. Thus, the



biomonitoring results suggest that chronic toxicity may not occur in the receiving stream at a dilution of 10:1. Chronic toxicity would be predicted to occur in the Bush River if the groundwater entered the receiving stream at the concentrations which occur in well CC-33B.

## 6.2 Hazard Assessment Evaluation

The groundwater may be considered a potentially hazardous material to the benthic biota of the Bush River when conservative groundwater assumptions are used (e.g., homogeneously mixed heavy metals and chlorinated organics, no chemical or biotic transformations of the DNAPLs, large release volumes through the sediments to the Bush River, etc.). The hazard to water column aquatic biota would rapidly dissipate as the groundwater materials are mixed in the receiving stream. Because the potential water quality impacts were judged to be minimal, a mixing zone approach by the State of Maryland which allows for local exceedences of water quality standards may be pursued.

The near-field (ULINE model) and far-field (dye-tracer model) screening level dilution models suggested that a total near-field dilution of approximately 42:1 for the application of Maryland's acute aquatic life criteria and a near-field dilution level of 168:1 for the application of chronic criteria would occur in the Bush River. Thus, contaminants introduced via Beach Point groundwater into Bush River receiving waters at a concentration of 42  $\mu\text{g/L}$  would be diluted locally to a concentration of approximately 1  $\mu\text{g/L}$  or less. When the dilution factors were applied to groundwater quality at Beach Point, none of the heavy metals or chlorinated aliphatic compounds exceeded Maryland's current acute or chronic aquatic life criteria. The dilution study showed that detectable concentrations of some of the chlorinated organics would occur in the receiving stream when the conservative assumptions concerning the groundwater contaminants were used in the model.

Although an argument can be made for a mixing zone, it is highly unlikely that the contaminant loads assumed in the near-field dilution model will ever occur in the Bush River. The conservative assumptions that were used in the hazard assessment should be evaluated further before a decision is made that the groundwater entering the Bush River is an environmental hazard and, thus, a mixing zone should be considered. A refinement of the assumptions would reduce the uncertainty regarding the volume of the discharge as well as the concentration of contaminants that may enter the receiving stream.

## SECTION 7

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APPENDIX 1

MICROTOX® ASSAYS CONDUCTED ON RAW (pH  $\approx$ 4) BEACH POINT  
GROUNDWATER (WELL CC-33B), CHRONIC HISTOPATHOLOGY  
EXPOSURE TANKS, AND DILUENT WATER

TABLE A1-1. MICROTOX® TEST RESULTS ON GRAB SAMPLES OF BEACH POINT 100% GROUNDWATER (pH  
 ≈4) TAKEN FROM WELL CC-33B<sup>a</sup>

Date of Sample	Microtox® 5-Min Readings			Microtox® 15-Min Readings		
	5-min EC50	95% Fiducial Limits	Slope	15-min EC50	95% Fiducial Limits	Slope
Mar 24	15.7	12.45-19.71	1.07	19.5	12.35-30.81	1.20
26	11.3	08.67-14.69	0.94	18.0	11.15-28.97	1.00
31	13.3	11.02-16.14	0.98	21.1	10.47-42.55	1.10
Apr 02	11.8	07.50-18.46	0.80	19.0	08.69-41.47	0.82
05	13.3	09.57-18.51	0.81	21.8	07.79-61.22	0.89
07	12.4	09.32-16.40	0.83	20.1	10.21-39.53	0.95
09	14.7	11.70-18.45	0.82	22.9	10.57-49.61	0.89
12	14.4	10.75-19.16	0.93	23.0	11.32-46.61	1.06
14	14.9	11.29-19.56	0.98	22.5	08.73-58.01	1.01
16	14.1	09.88-20.21	0.90	21.5	08.02-57.54	1.02
19	10.7	07.10-16.05	0.90	17.0	07.38-39.01	0.97
21	11.8	08.91-15.62	0.85	19.3	09.48-39.40	0.98
23	12.3	09.55-15.79	0.90	18.2	07.97-41.51	0.90
26	13.7	11.78-15.83	0.92	21.4	10.65-43.14	1.00
28	12.6	09.31-17.15	0.86	19.6	10.34-37.08	0.94
30	12.4	09.53-16.20	0.89	20.4	09.22-45.15	1.03
May 03	15.1	10.69-21.25	1.01	24.9	09.18-67.57	1.09
05	15.2	08.18-28.25	0.94	23.6	06.13-90.84	1.13
07	11.0	08.62-14.10	0.79	17.2	08.64-34.06	0.87
10	12.4	10.73-14.39	0.87	18.8	10.47-33.93	0.89
12	14.9	14.48-15.36	1.00	20.9	10.75-40.66	1.02
14	10.6	07.55-14.81	0.79	20.5	15.70-26.86	1.02
17	12.9	12.01-13.89	0.88	20.3	08.79-47.08	0.86
19	13.9	11.33-16.97	0.84	22.1	10.19-48.04	0.92
21	13.5	11.27-16.27	0.88	20.6	08.67-48.76	0.95
24	12.0	08.01-18.06	0.81	22.2	10.40-47.16	0.93
26	13.6	12.90-14.32	0.96	20.7	11.36-37.63	1.04
28	11.5	08.94-14.91	0.88	20.4	10.87-38.38	1.04
Jun 01	12.6	08.78-18.10	0.92	20.0	11.70-34.37	1.05
02	12.2	09.43-15.80	0.85	19.2	11.23-32.82	1.04

TABLE A1-1. (CONTINUED)

Date of Sample	Microtox® 5-Min Readings			Microtox® 15-Min Readings		
	5-min EC50	95% Fiducial Limits	Slope	15-min EC50	95% Fiducial Limits	Slope
Jun 04	10.8	07.65-15.37	0.82			
07	<sup>b</sup>			<sup>b</sup>		
09	14.7	13.43-16.11	1.04	21.4	11.09-41.33	1.12
10	13.6	11.89-15.51	0.99	20.3	10.57-38.86	0.98
15	13.0	09.71-17.43	0.94	19.7	09.15-42.35	0.99
16	14.1	12.23-16.32	0.95	20.0	11.25-35.65	1.00
18	16.0	12.97-19.63	0.90	21.8	11.46-41.67	0.86
21	15.7	14.41-17.14	1.05	23.0	16.04-32.87	1.02
23	14.1	11.31-17.54	1.02	22.4	12.09-41.49	1.03
25	15.4	10.14-23.52	0.95	22.0	08.32-57.97	0.86
28	17.3	14.52-20.64	0.97	24.2	09.90-59.13	0.88
30	16.8	14.09-20.13	1.05	25.3	11.26-56.62	0.94
Jul 02	19.5	14.57-26.03	1.08	26.4	10.25-67.97	0.95
05	<sup>c</sup>			<sup>c</sup>		
07	<sup>c</sup>			<sup>c</sup>		
09	<sup>c</sup>			<sup>c</sup>		
12	16.2	12.50-21.01	0.91	23.3	10.41-51.94	0.93
14	14.8	11.59-18.82	0.87	23.4	09.20-59.61	0.80
16	17.7	14.17-22.15	1.01	24.2	11.78-49.89	0.87
19	11.6	10.02-13.46	0.87	18.7	07.97-43.69	0.80
21	16.3	12.25-21.66	0.88	24.9	09.14-67.78	1.07
23	17.5	15.15-20.11	0.98	24.8	12.05-50.98	0.99
26	18.1	16.58-19.80	0.91	25.7	11.13-59.10	1.02
28	<sup>b</sup>			<sup>b</sup>		
30	17.0	11.08-26.24	1.24	23.1	13.36-39.81	1.26
Aug 02	16.1	14.61-17.77	0.86	23.8	12.26-46.21	1.00
05	15.6	13.71-17.70	0.79	22.7	09.53-54.16	0.86
06	17.2	13.86-21.33	0.85	28.8	15.58-53.17	1.21
09	19.6	17.98-21.31	1.02	30.1	12.93-70.19	0.95
11	20.8	18.16-23.89	0.93	32.4	11.26-93.20	0.82

TABLE A1-1. (CONTINUED)

Date of Sample	Microtox® 5-Min Readings			Microtox® 15-Min Readings		
	5-min EC50	95% Fiducial Limits	Slope	15-min EC50	95% Fiducial Limits	Slope
Aug 12	20.9	17.73-24.57	0.95	32.0	10.21-100.56	0.86
16	21.0	14.51-30.35	1.02	33.0	11.24-96.77	0.92
18	17.4	13.18-23.04	0.90	29.6	21.19-41.37	0.93
20	23.7	15.90-35.51	0.83	32.7	14.11-75.79	0.92
24	23.8	21.14-26.89	1.12	34.6	15.63-76.62	1.16
25	21.4	17.72-25.92	1.07	33.0	18.00-60.43	1.14
27	24.1	16.02-36.29	0.88	33.7	13.32-85.10	0.92
30	21.0	16.85-26.16	0.94	28.8	11.34-73.26	1.02
Sep 01	29.1	21.56-39.19	1.13	39.2	15.80-97.27	1.02
03	26.9	21.13-34.34	0.83	33.8	25.35-44.96	1.03
07	26.9	20.69-34.99	0.93	35.4	08.68-145.15	0.81
08	22.2	18.59-26.43	0.85	27.8	12.49-62.07	0.82
09	25.9	18.65-35.92	0.91	31.0	16.10-59.63	0.91
13	22.2	16.46-29.86	0.85	29.5	11.53-75.74	0.83
14	25.4	17.16-37.66	0.87	32.5	07.40-142.39	0.88
15	26.8	20.51-35.11	0.85	28.7	08.41-97.92	0.93
20	22.0	14.99-32.35	0.87	27.8	10.71-72.04	0.88
21	22.8	19.25-26.97	1.06	29.7	15.06-58.44	1.18
22	19.9	17.06-23.21	0.93	26.1	10.52-65.00	1.01
27	25.6	18.60-35.17	1.13	34.2	15.10-77.48	1.18
28	23.5	13.30-41.68	0.81	32.5	09.76-108.07	0.85
29	24.5	17.63-34.05	0.98	33.3	15.19-72.95	1.04
Oct 04	21.7	15.45-30.42	0.94	32.7	10.06-106.37	0.85
06	23.1	17.77-29.96	0.98	30.8	11.10-85.53	0.85
08	22.1	21.24-23.05	1.04	29.2	10.61-80.54	1.11
11	22.9	18.61-28.24	0.94	30.6	10.88-86.27	0.95
13	27.1	17.56-41.71	0.92	36.2	08.15-160.86	0.83
15	21.3	16.92-26.91	0.93	30.4	08.52-108.22	0.88
18	23.0	15.02-35.23	0.99	33.1	11.59-94.23	1.00
19	19.7	14.70-26.52	0.86	26.7	09.67-73.96	0.84
20	27.1	19.65-37.29	1.16	d		

TABLE A1-1. (CONTINUED)

Date of Sample	Microtox® 5-Min Readings			Microtox® 15-Min Readings		
	5-min EC50	95% Fiducial Limits	Slope	15-min EC50	95% Fiducial Limits	Slope
Oct 26	22.5	17.55-28.92	0.97	34.1	22.19-52.27	1.07
27	23.7	19.69-28.49	1.02	34.9	15.18-80.33	1.10
29	22.0	16.02-30.24	0.85	36.7	23.45-57.37	1.15
Nov 01	20.0	17.83-22.33	0.67	38.2	12.02-121.33	0.94
03	19.3	17.04-21.89	0.86	35.8	30.83-41.52	1.26
05	22.4	21.16-23.64	0.90	38.4	08.77-168.47	1.73
08	19.1	14.29-25.44	0.69	37.0	09.61-142.56	0.86
10	18.9	15.46-23.07	0.79	33.7	10.97-103.34	0.99
12	22.5	20.02-25.24	0.82	36.9	10.69-127.60	1.05
15	24.1	18.81-30.75	0.90	40.7	12.11-136.78	0.98
17	27.0	24.43-29.94	0.89	45.2	12.04-169.60	1.06
19	25.4	17.11-37.62	0.92	40.2	05.67-285.40	1.00
22	21.8	17.12-27.68	0.84	39.4	12.71-122.21	0.93
24	17.2	14.62-20.16	0.68	33.6	13.92-81.10	0.78
26	30.3	27.34-33.68	0.94	47.1	06.54-338.68	1.16
Dec 01	20.4	15.79-26.47	0.79	36.8	16.79-80.87	0.90
03	20.8	20.17-21.50	0.90	39.3	24.17-64.04	1.24
06	25.4	11.39-56.51	1.05	30.2	07.97-114.48	1.09

- <sup>a</sup> EC50s and 95% fiducial limits are expressed as percent groundwater by volume.  
<sup>b</sup> Microtox® instrument malfunctioned; sent to Microbics Corporation for repair.  
<sup>c</sup> Microtox® instrument was not available for use.  
<sup>d</sup> Lost data - dropped cuvette.

TABLE A1-2. MICROTOX® TEST RESULTS ON GRAB SAMPLES OF BEACH POINT 10% GROUNDWATER TAKEN FROM THE CHRONIC HISTOPATHOLOGY STUDY TANKS<sup>a</sup>

Date of Sample	Microtox® 5-Min Readings		Microtox® 15-Min Readings	
	5-min EC50	95% Fiducial Limits	15-min EC50	95% Fiducial Limits
Mar 24	-		-	
Mar 26	-		-	
Mar 31	-		-	
Apr 02	-		-	
Apr 05	-		-	
Apr 07	-		-	
Apr 09	-		-	
Apr 12	-		-	
Apr 14	-		-	
Apr 16	-		-	
Apr 19	-		-	
Apr 21	98.6	00.00-1x10 <sup>6</sup>	-	
Apr 23	-		-	
Apr 26	-		-	
Apr 28	-		-	
Apr 30	-		-	
May 03	-		-	
May 05	-		-	
May 07	-		-	
May 10	-		-	
May 12	-		-	
May 14	-		-	
May 17	-		-	
May 19	-		-	
May 21	-		-	
May 24	-		-	
May 26	-		-	
May 28	-		-	
Jun 01	-		-	



TABLE A1-2. (CONTINUED)

Date of Sample	Microtox® 5-Min Readings			Microtox® 15-Min Readings		
	5-min EC50	95% Fiducial Limits	Slope	15-min EC50	95% Fiducial Limits	Slope
Jun 02	-			-		
04	-			b		
07	b			b		
09	-			-		
10	-			-		
15	-			-		
16	-			-		
18	-			-		
21	-			-		
23	-			-		
25	-			-		
28	-			-		
30	-			-		
Jul 02	-			-		
05	c			c		
07	c			c		
09	c			c		
12	-			-		
14	-			-		
16	-			-		
19	-			-		
21	-			-		
23	-			-		
26	-			-		
28	b			b		
30	-			-		
Aug 02	-			-		
05	-			-		
06	-			-		
09	-			-		

TABLE A1-2. (CONTINUED)

Date of Sample	Microtox® 5-Min Readings			Microtox® 15-Min Readings		
	5-min EC50	95% Fiducial Limits	Slope	15-min EC50	95% Fiducial Limits	Slope
Aug 11	-			-		
12	-			-		
16	-			-		
18	-			-		
20	-			-		
24	-			-		
25	-			-		
27	-			-		
30	-			-		
Sep 01	-			-		
03	-			-		
07	-			-		
08	-			-		
09	-			-		
13	-			-		
14	-			-		
15	-			-		
20	-			-		
21	-			-		
22	-			-		
27	-			-		
28	-			-		
29	-			-		
Oct 04	-			-		
06	-			-		
08	-			-		
11	-			-		
13	-			-		
15	-			-		
18	-			-		

TABLE A1-2. (CONTINUED)

Date of Sample	Microtox® 5-Min Readings			Microtox® 15-Min Readings		
	5-min EC50	95% Fiducial Limits	Slope	15-min EC50	95% Fiducial Limits	Slope
19	-			-		
20	-			-		
26	-			-		
27	-			-		
29	-			-		
Nov 01	-			-		
03	-			-		
05	-			-		
08	-			-		
10	-			-		
12	-			-		
15	-			-		
17	-			-		
19	-			-		
22	-			-		
24	-			-		
26	-			-		
Dec 01	-			-		
03	-			-		
06	-			-		

<sup>a</sup> EC50s and 95% fiducial limits are expressed as percent groundwater by volume.

<sup>b</sup> Microtox® instrument malfunctioned; sent to Microbics Corporation for repair.

<sup>c</sup> Microtox® instrument was not available for use.

TABLE A1-3. MICROTOX® TEST RESULTS ON GRAB SAMPLES OF BEACH POINT 1% GROUNDWATER TAKEN FROM THE CHRONIC HISTOPATHOLOGY STUDY TANKS<sup>a</sup>

Date of Sample	Microtox® 5-Min Readings			Microtox® 15-Min Readings		
	5-min EC50	95% Fiducial Limits	Slope	15-min EC50	95% Fiducial Limits	Slope
Mar 24	-			-		
26	-			-		
31	-			-		
Apr 02	-			-		
05	-			-		
07	-			-		
09	-			-		
12	-			-		
14	-			-		
16	-			-		
19	-			-		
21	-			-		
23	-			-		
26	-			-		
28	-			-		
30	-			-		
May 03	-			-		
05	-			-		
07	-			-		
10	-			-		
12	-			-		
14	-			-		
17	-			-		
19	-			-		
21	-			-		
24	-			-		
26	-			-		
28	-			-		
Jun 01	-			-		

TABLE A1-3. (CONTINUED)

Date of Sample	Microtox® 5-Min Readings			Microtox® 15-Min Readings		
	5-min EC50	95% Fiducial Limits	Slope	15-min EC50	95% Fiducial Limits	Slope
Jun 02	-			-		
04	-			b		
07	b			b		
09	-			-		
10	-			-		
15	-			-		
16	-			-		
18	-			-		
21	-			-		
23	-			-		
25	-			-		
28	-			-		
30	-			-		
Jul 02	-			-		
05	c			c		
07	c			c		
09	c			c		
12	-			-		
14	-			-		
16	-			-		
19	-			-		
21	-			-		
23	-			-		
26	-			-		
28	b			-		
30	-			-		
Aug 02	-			-		
05	-			-		
06	-			-		
09	-			-		
				52.7 <sup>d</sup>	07.90-351.71	1.49

TABLE A1-3. (CONTINUED)

Date of Sample	Microtox® 5-Min Readings			Microtox® 15-Min Readings		
	5-min EC50	95% Fiducial Limits	Slope	15-min EC50	95% Fiducial Limits	Slope
Aug 11	-			-		
12	-			-		
16	-			-		
18	-			-		
20	-			-		
24	-			-		
25	-			-		
27	-			-		
30	-			-		
Sep 01	-			-		
03	-			-		
07	-			-		
08	-			-		
09	-			-		
13	-			-		
14	-			-		
15	-			-		
20	-			-		
21	-			-		
22	-			-		
27	-			-		
28	-			-		
29	-			-		
Oct 04	-			-		
06	-			-		
08	-			-		
11	-			-		
13	-			-		
15	-			-		
18	-			-		

TABLE A1-3. (CONTINUED)

Date of Sample	Microtox® 5-Min Readings			Microtox® 15-Min Readings		
	5-min EC50	95% Fiducial Limits	Slope	15-min EC50	95% Fiducial Limits	Slope
19	-			-		
20	-			-		
26	-			-		
27	-			-		
29	-			-		
Nov 01	-			-		
03	-			-		
05	-			-		
08	-			-		
10	-			-		
12	-			-		
15	-			-		
17	-			-		
19	-			-		
22	-			-		
24	-			-		
26	-			-		
Dec 01	-			-		
03	-			-		
06	-			-		

- <sup>a</sup> EC50s and 95% fiducial limits are expressed as percent groundwater by volume.  
<sup>b</sup> Microtox® instrument malfunctioned; sent to Microbics Corporation for repair.  
<sup>c</sup> Microtox® instrument was not available for use.  
<sup>d</sup> Microtox® instrument malfunctioning; reading may be incorrect.

TABLE A1-4. MICROTOX® TEST RESULTS ON GRAB SAMPLES OF APG-EA DILUENT WATER<sup>a</sup>

Date of Sample	Microtox® 5-Min Readings			Microtox® 15-Min Readings		
	5-min EC50	95% Fiducial Limits	Slope	15-min EC50	95% Fiducial Limits	Slope
Mar 26	-			-		
Mar 31	-			-		
Apr 02	-			-		
Apr 05	-			-		
Apr 07	-			-		
Apr 09	-			-		
Apr 14	-			-		
Apr 21	-			-		
Apr 28	-			-		
May 07	-			-		
May 12	-			-		
May 19	-			-		
May 26	-			-		
Jun 04	b			b		
Jun 09	-			-		
Jun 16	-			-		
Jun 23	-			-		
Jun 30	-			-		
Jul 07	c			c		
Jul 14	-			-		
Jul 21	-			-		
Jul 28	b			b		
Aug 06	-			-		
Aug 11	-			-		
Aug 18	-			-		
Aug 25	-			-		
Sep 01	-			-		
Sep 07	-			-		
Sep 15	-			-		



TABLE A1-4. (CONTINUED)

Date of Sample	Microtox® 5-Min Readings			Microtox® 15-Min Readings		
	5-min EC50	95% Fiducial Limits	Slope	15-min EC50	95% Fiducial Limits	Slope
Sep 22	-			-		
Sep 27	-			-		
Oct 06	-			-		
Oct 13	-			-		
Oct 20	-			-		
Oct 27	-			-		
Nov 03	-			-		
Nov 10	-			-		
Nov 19	-			-		
Nov 24	-			-		
Dec 01	-			-		

- <sup>a</sup> EC50s and 95% fiducial limits are expressed as percent groundwater by volume.  
<sup>b</sup> Microtox® instrument malfunctioned; sent to Microbics Corporation for repair.  
<sup>c</sup> Microtox® instrument was not available for use.  
<sup>d</sup> Electrical power surge caused an interrupt in the circuit; therefore, the 15-min readings could not be obtained.

APPENDIX 2

MICROTOX® ASSAYS CONDUCTED ON BEACH POINT  
BUFFERED (pH  $\approx$ 7) GROUNDWATER (WELL CC-33B)  
AND pH OF SAMPLES USED IN ASSAYS

TABLE A2-1. MICROTOX® TEST RESULTS ON GRAB SAMPLES OF BEACH POINT BUFFERED 100% GROUNDWATER (pH ≈7) TAKEN FROM WELL CC-33B<sup>a</sup>

Date of Sample	Rep	Microtox® 5-Min Readings			Microtox® 15-Min Readings		
		5-min EC50	95% Fiducial Limits	Slope	15-min EC50	95% Fiducial Limits	Slope
Apr 28	1	24.8	23.24-26.46	1.02	29.3	24.36-35.25	1.05
	2	33.3	25.01-44.26	1.05	38.0	34.63-41.75	1.00
May 07	1	16.9	07.85-36.22	0.76	18.4	09.59-35.13	0.72
	2	18.7	12.99-26.88	0.86	22.3	14.69-33.95	0.82
12	1	18.8	15.95-22.10	0.85	22.8	21.75-23.83	0.82
	2	22.0	20.81-23.22	0.90	26.6	20.09-35.33	0.81
19	1	17.5	13.04-23.54	0.86	21.8	16.30-29.14	0.85
	2	23.1	20.52-26.10	0.94	29.3	28.03-30.55	0.83
26	1	23.0	18.51-28.67	0.86	27.8	23.10-33.37	0.82
	2	22.4 <sub>b</sub>	18.50-27.18	0.77	25.2 <sub>b</sub>	21.14-29.92	0.75
Jun 04	1	<sub>b</sub>			<sub>b</sub>		
	2	22.3	20.89-23.77	0.82	26.8	22.07-32.45	0.82
09	1	23.1	19.89-26.75	0.95	28.4	21.91-36.72	0.92
	2	20.9	17.39-25.00	0.96	22.7	18.40-28.06	0.88
16	1	21.3	15.63-29.00	1.01	25.1	19.05-33.17	0.97
	2	27.0	24.92-29.34	0.84	32.8	26.74-40.18	0.81
23	1	24.8	19.61-31.38	0.90	28.0	21.37-36.64	0.82
	2	27.2	20.84-35.57	0.99	31.6	23.29-42.77	0.94
30	1	28.2 <sub>c</sub>	17.19-46.21	0.87	33.3 <sub>c</sub>	17.70-62.71	0.86
	2	<sub>c</sub>			<sub>c</sub>		
Jul 07	1	23.8	13.82-40.83	0.92	29.0	13.47-62.58	0.90
	2	22.7	21.45-24.05	0.84	28.3	25.34-31.56	0.83
14	1	21.7	18.00-26.23	0.80	25.5	23.88-27.34	0.76
	2	28.8 <sub>b</sub>	22.46-36.89	0.87	34.9 <sub>b</sub>	24.01-50.62	0.86
21	1	<sub>b</sub>			<sub>b</sub>		
	2	<sub>b</sub>			<sub>b</sub>		
28	1						
	2						

TABLE A2-1. (CONTINUED)

Date of Sample	Rep	Microtox® 5-Min Readings			Microtox® 15-Min Readings		
		5-min EC50	95% Fiducial Limits	Slope	15-min EC50	95% Fiducial Limits	Slope
Aug 06	1	27.7	24.00-31.98	0.83	37.3	29.64-47.01	0.82
	2	30.2	26.32-34.75	0.98	37.4	27.14-51.48	1.09
	11	27.2	22.70-32.53	0.89	30.7	20.42-46.25	0.86
	2	28.8	17.35-47.88	0.79	37.1	18.51-74.25	0.69
18	1	21.6	13.40-34.75	1.10	23.8	14.11-40.09	1.04
	2	32.5	27.44-38.45	1.07	37.2	26.91-51.51	1.08
	1	33.7	29.52-38.48	0.94	43.3	39.54-47.48	0.93
	2	45.6	23.96-86.94	0.77	62.2	28.33-136.53	0.76
Sep 01	1	38.7	30.26-49.52	1.01	45.9	35.01-60.30	1.00
	2	46.8	22.72-96.55	0.80	70.1	30.92-158.88	0.68
	1	41.6	23.19-74.56	0.96	49.6	28.50-86.25	1.03
	2	50.4	32.13-79.02	0.76	68.2	25.62-181.54	0.67
07	1	33.1	29.74-36.81	0.78	42.0	36.27-48.55	0.79
	2	38.1	32.91-44.08	0.96	47.9	32.20-71.21	0.97
	1	38.9	21.19-71.41	0.73	47.3	15.33-145.90	0.61
	2	40.7	05.45-304.23	1.34	44.5	04.19-472.05	1.58
27	1	39.5	34.20-45.66	0.99	d		
	2	43.0	20.66-89.66	1.28	d		
	1	40.9	28.98-57.74	0.90	48.7	34.07-69.75	0.87
	2	43.1	32.96-56.41	0.75	54.9	33.61-89.66	0.67
13	1	52.3	45.56-60.19	0.85	65.2	59.34-71.73	0.82
	2	45.0	37.34-54.24	0.92	60.5	55.41-66.06	0.88
	1	39.9	27.91-56.95	0.96	47.9	28.60-80.29	0.88
	2	43.7	30.48-62.69	0.88	57.7	52.74-63.09	0.96
27	1	39.1	33.67-45.44	0.95	53.8	40.25-71.82	0.96
	2	45.4	34.58-59.64	0.89	69.1	40.14-118.93	0.87

TABLE A2-1. (CONTINUED)

Date of Sample	Rep	Microtox® 5-Min Readings			Microtox® 15-Min Readings		
		5-min EC50	95% Fiducial Limits	Slope	15-min EC50	95% Fiducial Limits	Slope
Nov 03	1	39.2	23.70-64.95	0.91	53.2	30.03-94.12	0.84
	2	54.7	38.84-76.94	0.88	83.5	33.51-208.14	0.88
	10	41.7	31.91-54.48	1.02	52.0	39.93-67.61	1.07
	2	48.7	36.39-65.12	0.84	66.4	41.14-107.28	0.86
19	1	50.9	27.15-95.30	0.74	69.6	18.91-256.33	0.68
	2	54.9	51.79-58.15	0.74	89.0	53.86-147.02	0.63
	1	40.5	35.50-46.11	1.01	55.7	46.12-67.28	0.89
	2	38.3	32.19-45.68	0.95	50.8	42.44-60.86	0.96
Dec 01	1	46.5	30.01-72.09	0.75	67.4	44.82-101.45	0.78
	2	59.1	46.34-75.40	0.81	95.6	30.11-303.76	0.72

- <sup>a</sup> EC50s and 95% fiducial limits are expressed as percent groundwater by volume.  
<sup>b</sup> Microtox® instrument malfunctioned; sent to Microbics Corporation for repair.  
<sup>c</sup> Microtox® instrument was not available for use.  
<sup>d</sup> Electrical power surge caused an interrupt in the circuit; consequently, the 15-min readings were lost.

TABLE A2-2. pH OF THE RAW AND BUFFERED 100% GROUNDWATER USED  
IN THE MICROTOX® ASSAY

Date of Sample	Rep	Raw Groundwater	<u>Buffered Groundwater</u>	
			Initial	Final
Apr 28	1	4.04	7.07	7.16
	2	4.04	7.07	7.16
May 07	1	3.99	7.13	7.28
	2	3.99	7.13	7.28
12	1	4.01	7.09	7.16
	2	4.01	7.09	7.16
19	1	3.97	7.05	7.12
	2	3.97	7.05	7.12
26	1	4.00	7.11	7.19
	2	4.00	7.11	7.19
Jun 09	1	4.03	7.00	7.02
	2	4.03	7.00	7.02
16	1	4.06	7.05	7.07
	2	4.06	7.05	7.07
23	1	4.02	7.01	7.03
	2	4.02	7.01	7.03
30	1	4.08	7.01	7.11
	2	4.08	7.01	7.11
Jul 07	1	a		
	2	a		
14	1	4.02	6.90	6.87
	2	4.02	6.90	6.87
21	1	4.06	6.99	7.07
	2	4.06	6.99	7.07
28	1	b		
Aug 06	1	3.98	6.98	7.01
	2	3.98	6.98	7.01
11	1	3.98	6.94	7.01
	2	3.98	6.94	7.01
18	1	4.02	7.04	7.09
	2	4.02	7.04	7.09
Aug 25	1	4.05	6.95	6.98
	2	4.05	6.95	6.98
Sep 01	1	4.06	7.11	7.18
	2	4.06	7.11	7.18
07	1	4.01	6.93	6.96
	2	4.01	6.93	6.96
15	1	4.01	7.02	7.13
	2	4.01	7.02	7.13
22	1	3.99	7.00	7.07
	2	3.99	7.00	7.07
27	1	3.99	7.06	7.11
	2	3.99	7.06	7.11

TABLE A2-2. (CONTINUED)

Date of Sample	Rep	Raw Groundwater	<u>Buffered Groundwater</u>	
			Initial	Final
Oct 06	1	4.02	7.01	7.11
	2	4.02	7.01	7.11
	1	4.03	6.97	7.12
	2	4.03	6.97	7.12
	1	4.07	7.09	7.18
	2	4.07	7.09	7.18
	1	4.08	7.00	7.10
	2	4.08	7.00	7.10
Nov 03	1	4.00	6.94	7.02
	2	4.00	6.94	7.02
	1	4.03	7.00	7.10
	2	4.03	7.00	7.10
	1	3.99	6.93	7.09
	2	3.99	6.93	7.09
	1	4.02	7.04	7.12
	2	4.02	7.04	7.12
Dec 01	1	4.05	7.01	7.09
	2	4.05	7.01	7.09

<sup>a</sup> Microtox® instrument was not available for use.

<sup>b</sup> Microtox® instrument malfunctioned and was sent to Microbics Corporation for repair.

### APPENDIX 3

ROTIFER 24-H ACUTE TEST CONDUCTED ON BEACH POINT  
RAW (pH  $\approx$ 4) GROUNDWATER (WELL CC-33B)  
(TEST NO. 1)

Test Method:	Rotifer Toxkit™ Screening Test (Bio-Response Systems, Halifax, Nova Scotia)
Type of Test:	Static
Date:	April 10-12, 1993
Investigator:	S. D. Turley
Laboratory:	UMD/WREC
Groundwater:	
Source:	APG-EA Beach Point Well CC-33B
Chemical Characteristics:	See Appendix 48
Test Medium:	Rotifer Toxkit™ synthetic medium
Test Organism:	
Scientific Name:	<u>Brachionus rubens</u>
Age at Start of Test:	<4 h after hatch
Source:	Rotifer Toxkit™ cyst
Experimental Chambers:	
Material:	Glass petri dish
Test Solution Volume:	10 mL
No. Organisms/Replicate:	10
No. Organisms/Treatment:	30
Loading:	n/a
Lighting:	Fluorescent; 60-85 foot candles
Aeration:	None
Endpoint:	Mortality



## Water Quality:

Dissolved Oxygen (mg/L):	Mean: 8.5 Range: 8.2-8.8 APHA Standards Methods (1989)
pH (std. units):	Mean: 5.8 Range: 4.0-6.7 APHA Standards Methods (1989)
Conductivity ( $\mu$ mhos/cm):	APG-EA diluent water: 140 100% groundwater: 1500
Alkalinity (mg/L as $\text{CaCO}_3$ ):	APG-EA diluent water: 50 100% groundwater: n/a
Hardness (mg/L as $\text{CaCO}_3$ ):	APG-EA diluent water: 48 100% groundwater: n/a
Temperature ( $^{\circ}\text{C}$ ):	25 $\pm$ 0.5

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## Results:

100% Beach Point raw groundwater killed 80% of the rotifers in 24 h (Table A3-1). The 24-h LC50, which was determined by the moving average angle method, is as follows:

24-h LC50 = 71.9% raw groundwater by volume (95% confidence limits = 64.26-83.39).

TABLE A3-1. ROTIFER BEACH POINT RAW GROUNDWATER TOXICITY TEST  
DATA (TEST NO. 1) - SURVIVAL AFTER 24 HOURS OF  
EXPOSURE

Concentration (% by Volume)	Rep	Number Tested	No. Alive at End of Test	Percent Alive
Growth Medium	1	10	10	100
	2	10	10	100
	3	10	10	100
APG-EA Diluent Water	1	10	10	100
	2	10	10	100
	3	10	10	100
18	1	10	10	100
	2	10	10	100
	3	10	9	90
56	1	10	8	80
	2	10	9	90
	3	10	10	100
100	1	10	3	30
	2	10	1	10
	3	10	2	20

#### APPENDIX 4

ROTIFER 24-H ACUTE TEST CONDUCTED ON BEACH POINT  
BUFFERED (pH  $\approx$ 7) GROUNDWATER (WELL CC-33B)  
(TEST NO. 1)

Test Method:	Rotifer Toxkit™ Screening Test (Bio-Response Systems, Halifax, Nova Scotia)
Type of Test:	Static
Date:	April 10-12, 1993
Investigator:	S. D. Turley
Laboratory:	UMD/WREC
Groundwater:	
Source:	APG-EA Beach Point Well CC-33B
Chemical Characteristics:	See Appendix 48
Test Medium:	Rotifer Toxkit™ synthetic medium
Test Organism:	
Scientific Name:	<u>Brachionus rubens</u>
Age at Start of Test:	<4 h after hatch
Source:	Rotifer Toxkit™ cyst
Experimental Chambers:	
Material:	Glass Petri dish
Test Solution Volume:	10 mL
No. Organisms/Replicate:	10
No. Organisms/Treatment:	30
Loading:	n/a
Lighting:	Fluorescent; 60-85 foot candles
Aeration:	None
pH Buffer:	10 N NaOH
Endpoint:	Mortality

## Water Quality:

Dissolved Oxygen (mg/L):	Mean: 8.4 Range: 8.1-8.8 APHA Standards Methods (1989)
pH (std. units):	Mean: 6.8 Range: 6.6-7.0 APHA Standards Methods (1989)
Conductivity ( $\mu$ mhos/cm):	APG-EA diluent water: 140 100% groundwater: 1700
Alkalinity (mg/L as $\text{CaCO}_3$ ):	APG-EA diluent water: 50 100% groundwater: 80
Hardness (mg/L as $\text{CaCO}_3$ ):	APG-EA diluent water: 48 100% groundwater: 280
Temperature ( $^{\circ}\text{C}$ ):	25 $\pm$ 0.5

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## Results:

The buffered groundwater did not affect rotifer survival. The data are summarized in Table A4-1.

TABLE A4-1. ROTIFER BEACH POINT BUFFERED GROUNDWATER TOXICITY  
TEST DATA (TEST NO. 1) - SURVIVAL AFTER 24 HOURS OF  
EXPOSURE

Concentration (% by Volume)	Rep	Number Tested	No. Alive at End of Test	Percent Alive
Growth Medium	1	10	10	100
	2	10	10	100
	3	10	10	100
56	1	10	9	90
	2	10	9	90
	3	10	10	100
100	1	10	8	80
	2	10	8	80
	3	10	9	90

## APPENDIX 5

### ROTIFER 24-H ACUTE TEST CONDUCTED ON BEACH POINT RAW (pH $\approx$ 4) GROUNDWATER (WELL CC-33B) (TEST NO. 2)

Test Method:	Rotifer Toxkit™ Screening Test (Bio-Response Systems, Halifax, Nova Scotia)
Type of Test:	Static
Date:	June 2-4, 1993
Investigator:	S. D. Turley
Laboratory:	UMD/WREC
Groundwater:	
Source:	APG-EA Beach Point Well CC-33B
Chemical Characteristics:	See Appendix 48
Test Medium:	Rotifer Toxkit™ synthetic medium
Test Organism:	
Scientific Name:	<u>Brachionus rubens</u>
Age at Start of Test:	<4 h after hatch
Source:	Rotifer Toxkit™ cyst
Experimental Chambers:	
Material:	Glass petri dish
Test Solution Volume:	10 mL
No. Organisms/Replicate:	10
No. Organisms/Treatment:	30
Loading:	n/a
Lighting:	Fluorescent; 60-85 foot candles
Aeration:	None
Endpoint:	Mortality

## Water Quality:

Dissolved Oxygen (mg/L):	Mean: 8.3 Range: 8.1-8.4 APHA Standards Methods (1989)
pH (std. units):	Mean: 5.9 Range: 3.9-6.8 APHA Standards Methods (1989)
Conductivity ( $\mu$ mhos/cm):	APG-EA diluent water: 150 100% groundwater: 1400
Alkalinity (mg/L as $\text{CaCO}_3$ ):	APG-EA diluent water: 55 100% groundwater: n/a
Hardness (mg/L as $\text{CaCO}_3$ ):	APG-EA diluent water: 50 100% groundwater: n/a
Temperature ( $^{\circ}\text{C}$ ):	25 $\pm$ 0.5

---

## Results:

100% Beach Point raw groundwater killed 87% of the rotifers in 24 h (Table A5-1). The 24-h LC50, which was determined by the moving average angle method, is as follows:

24-h LC50 = 64.4% raw groundwater by volume (95% confidence limits = 57.64-73.54).

TABLE A5-1. ROTIFER BEACH POINT RAW GROUNDWATER TOXICITY TEST  
DATA (TEST NO. 2) - SURVIVAL AFTER 24 HOURS OF  
EXPOSURE

Concentration (% by Volume)	Rep	Number Tested	No. Alive at End of Test	Percent Alive
Growth Medium	1	10	10	100
	2	10	10	100
	3	10	10	100
APG-EA Diluent Water	1	10	10	100
	2	10	10	100
	3	10	10	100
18	1	10	10	100
	2	10	10	100
	3	10	10	100
32	1	10	9	90
	2	10	10	100
	3	10	9	90
56	1	10	8	80
	2	10	7	70
	3	10	7	70
100	1	10	1	10
	2	10	0	0
	3	10	3	30



## APPENDIX 6

### ROTIFER 24-H ACUTE TEST CONDUCTED ON BEACH POINT BUFFERED (pH $\approx$ 7) GROUNDWATER (WELL CC-33B) (TEST NO. 2)

Test Method:	Rotifer Toxkit™ Screening Test (Bio-Response Systems, Halifax, Nova Scotia)
Type of Test:	Static
Date:	June 2-4, 1993
Investigator:	S. D. Turley
Laboratory:	UMD/WREC
Groundwater:	
Source:	APG-EA Beach Point Well CC-33B
Chemical Characteristics:	See Appendix 48
Test Medium:	Rotifer Toxkit™ synthetic medium
Test Organism:	
Scientific Name:	<u>Brachionus rubens</u>
Age at Start of Test:	<4 h after hatch
Source:	Rotifer Toxkit™ cyst
Experimental Chambers:	
Material:	Glass Petri dish
Test Solution Volume:	10 mL
No. Organisms/Replicate:	10
No. Organisms/Treatment:	30
Loading:	n/a
Lighting:	Fluorescent; 60-85 foot candles
Aeration:	None
pH Buffer:	10 N NaOH
Endpoint:	Mortality

## Water Quality:

Dissolved Oxygen (mg/L):	Mean: 7.5 Range: 6.5-8.3 APHA Standards Methods (1989)
pH (std. units):	Mean: 6.7 Range: 6.3-7.0 APHA Standards Methods (1989)
Conductivity ( $\mu$ mhos/cm):	APG-EA diluent water: 150 100% groundwater: 1400
Alkalinity (mg/L as $\text{CaCO}_3$ ):	APG-EA diluent water: 55 100% groundwater: 100
Hardness (mg/L as $\text{CaCO}_3$ ):	APG-EA diluent water: 50 100% groundwater: 170
Temperature ( $^{\circ}\text{C}$ ):	25 $\pm$ 0.5

---

## Results:

The 100% buffered groundwater killed 33% of the rotifers; therefore, an LC50 could not be obtained since <50% mortality occurred. A summary of the mortality data is given in Table A6-1.

TABLE A6-1. ROTIFER BEACH POINT BUFFERED GROUNDWATER TOXICITY  
TEST DATA (TEST NO. 2) - SURVIVAL AFTER 24 HOURS OF  
EXPOSURE

Concentration (% by Volume)	Rep	Number Tested	No. Alive at End of Test	Percent Alive
Growth Medium	1	10	10	100
	2	10	10	100
	3	10	10	100
32	1	10	10	100
	2	10	10	100
	3	10	9	90
56	1	10	9	90
	2	10	8	80
	3	10	9	90
100	1	10	5	50
	2	10	7	70
	3	10	8	80

## APPENDIX 7

### ROTIFER 24-H ACUTE TEST CONDUCTED ON BEACH POINT RAW (pH $\approx$ 4) GROUNDWATER (WELL CC-33B) (TEST NO. 3)

Test Method:	Rotifer Toxkit™ Screening Test (Bio-Response Systems, Halifax, Nova Scotia)
Type of Test:	Static
Date:	August 24-26, 1993
Investigator:	S. D. Turley
Laboratory:	UMD/WREC
Groundwater:	
Source:	APG-EA Beach Point Well CC-33B
Chemical Characteristics:	See Appendix 48
Test Medium:	Rotifer Toxkit™ synthetic medium
Test Organism:	
Scientific Name:	<u>Brachionus rubens</u>
Age at Start of Test:	<4 h after hatch
Source:	Rotifer Toxkit™ cyst
Experimental Chambers:	
Material:	Glass petri dish
Test Solution Volume:	10 mL
No. Organisms/Replicate:	10
No. Organisms/Treatment:	30
Loading:	n/a
Lighting:	Fluorescent; 60-85 foot candles
Aeration:	None
Endpoint:	Mortality

## Water Quality:

Dissolved Oxygen (mg/L):	Mean: 8.3 Range: 8.0-8.7 APHA Standards Methods (1989)
pH (std. units):	Mean: 5.9 Range: 3.9-6.7 APHA Standards Methods (1989)
Conductivity ( $\mu$ mhos/cm):	APG-EA diluent water: 150 100% groundwater: 1800
Alkalinity (mg/L as $\text{CaCO}_3$ ):	APG-EA diluent water: 50 100% groundwater: n/a
Hardness (mg/L as $\text{CaCO}_3$ ):	APG-EA diluent water: 52 100% groundwater: n/a
Temperature ( $^{\circ}\text{C}$ ):	25 $\pm$ 0.5

---

## Results:

100% Beach Point raw groundwater killed 80% of the rotifers in 24 h (Table A7-1). The 24-h LC50, which was determined by the moving average angle method, is as follows:

24-h LC50 = 70.2% raw groundwater by volume (95% confidence limits = 62.37-82.03).

TABLE A7-1. ROTIFER BEACH POINT RAW GROUNDWATER TOXICITY TEST  
DATA (TEST NO. 3) - SURVIVAL AFTER 24 HOURS OF  
EXPOSURE

Concentration (% by Volume)	Rep	Number Tested	No. Alive at End of Test	Percent Alive
Growth Medium	1	10	10	100
	2	10	9	90
	3	10	10	100
APG-EA Diluent Water	1	10	10	100
	2	10	10	100
	3	10	10	100
10	1	10	10	100
	2	10	10	100
	3	10	9	90
18	1	10	10	100
	2	10	10	100
	3	10	10	100
32	1	10	9	90
	2	10	10	100
	3	10	10	100
56	1	10	8	80
	2	10	7	70
	3	10	9	90
100	1	10	2	20
	2	10	3	30
	3	10	1	10

## APPENDIX 8

### ROTIFER 24-H ACUTE TEST CONDUCTED ON BEACH POINT BUFFERED (pH $\approx$ 7) GROUNDWATER (WELL CC-33B) (TEST NO. 3)

Test Method:	Rotifer Toxkit™ Screening Test (Bio-Response Systems, Halifax, Nova Scotia)
Type of Test:	Static
Date:	August 24-26, 1993
Investigator:	S. D. Turley
Laboratory:	UMD/WREC
Groundwater:	
Source:	APG-EA Beach Point Well CC-33B
Chemical Characteristics:	See Appendix 48
Test Medium:	Rotifer Toxkit™ synthetic medium
Test Organism:	
Scientific Name:	<u>Brachionus rubens</u>
Age at Start of Test:	<4 h after hatch
Source:	Rotifer Toxkit™ cyst
Experimental Chambers:	
Material:	Glass Petri dish
Test Solution Volume:	10 mL
No. Organisms/Replicate:	10
No. Organisms/Treatment:	30
Loading:	n/a
Lighting:	Fluorescent; 60-85 foot candles
Aeration:	None
pH Buffer:	10 N NaOH
Endpoint:	Mortality

Water Quality:

Dissolved Oxygen (mg/L):	Mean: 8.2
	Range: 7.9-8.4
	APHA Standards Methods (1989)

pH (std. units):	Mean: 7.1
	Range: 6.9-7.7
	APHA Standards Methods (1989)

Conductivity ( $\mu$ mhos/cm):	APG-EA diluent water: 150
	100% groundwater: 1900

Alkalinity (mg/L as $\text{CaCO}_3$ ):	APG-EA diluent water: 50
	100% groundwater: 100

Hardness (mg/L as $\text{CaCO}_3$ ):	APG-EA diluent water: 48
	100% groundwater: 210

Temperature ( $^{\circ}\text{C}$ ):	25 $\pm$ 0.5
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Results:

The buffered groundwater did not affect rotifer survival. The data are summarized in Table A8-1.



TABLE A8-1. ROTIFER BEACH POINT BUFFERED GROUNDWATER TOXICITY  
TEST DATA (TEST NO. 3) - SURVIVAL AFTER 24 HOURS OF  
EXPOSURE

Concentration (% by Volume)	Rep	Number Tested	No. Alive at End of Test	Percent Alive
Growth Medium	1	10	10	100
	2	10	9	90
	3	10	10	100
18	1	10	10	100
	2	10	10	100
	3	10	10	100
32	1	10	9	90
	2	10	10	100
	3	10	10	100
56	1	10	9	90
	2	10	10	100
	3	10	8	80
100	1	10	8	80
	2	10	6	60
	3	10	7	70

## APPENDIX 9

### ROTIFER 24-H ACUTE TEST CONDUCTED ON BEACH POINT RAW (pH $\approx$ 4) GROUNDWATER (WELL CC-33B) (TEST NO. 4)

Test Method:	Rotifer Toxkit™ Screening Test (Bio-Response Systems, Halifax, Nova Scotia)
Type of Test:	Static
Date:	December 1-3, 1993
Investigator:	S. D. Turley
Laboratory:	UMD/WREC
Groundwater:	
Source:	APG-EA Beach Point Well CC-33B
Chemical Characteristics:	See Appendix 48
Test Medium:	Rotifer Toxkit™ synthetic medium
Test Organism:	
Scientific Name:	<u>Brachionus rubens</u>
Age at Start of Test:	<4 h after hatch
Source:	Rotifer Toxkit™ cyst
Experimental Chambers:	
Material:	Glass petri dish
Test Solution Volume:	10 mL
No. Organisms/Replicate:	10
No. Organisms/Treatment:	30
Loading:	n/a
Lighting:	Fluorescent; 60-85 foot candles
Aeration:	None
Endpoint:	Mortality

## Water Quality:

Dissolved Oxygen (mg/L):	Mean: 8.6 Range: 8.3-8.9 APHA Standards Methods (1989)
pH (std. units):	Mean: 6.1 Range: 3.8-7.7 APHA Standards Methods (1989)
Conductivity ( $\mu$ mhos/cm):	APG-EA diluent water: 150 100% groundwater: 1750 APHA Standards Methods (1989)
Alkalinity (mg/L as $\text{CaCO}_3$ ):	APG-EA diluent water: 50 100% groundwater: n/a APHA Standards Methods (1989)
Hardness (mg/L as $\text{CaCO}_3$ ):	APG-EA diluent water: 54 100% groundwater: n/a APHA Standards Methods (1989)
Temperature ( $^{\circ}\text{C}$ ):	25 $\pm$ 0.5

---

## Results:

100% Beach Point raw groundwater killed 53% of the rotifers in 24 h (Table A9-1). The 24-h LC50, which was determined by the moving average angle method, is as follows:

24-h LC50 = 94.5% raw groundwater by volume (95% confidence limits = 75.84-147.56).

TABLE A9-1. ROTIFER BEACH POINT RAW GROUNDWATER TOXICITY TEST  
DATA (TEST NO. 4) - SURVIVAL AFTER 24 HOURS OF  
EXPOSURE

Concentration (% by Volume)	Rep	Number Tested	No. Alive at End of Test	Percent Alive
Growth Medium	1	10	10	100
	2	10	9	90
	3	10	10	100
APG-EA Diluent Water	1	10	10	100
	2	10	10	100
	3	10	8	80
10	1	10	10	100
	2	10	10	100
	3	10	10	100
18	1	10	9	90
	2	10	10	100
	3	10	10	100
32	1	10	9	90
	2	10	9	90
	3	10	10	100
56	1	10	8	80
	2	10	10	100
	3	10	8	80
100	1	10	6	60
	2	10	4	40
	3	10	4	40

APPENDIX 10

ROTIFER 24-H ACUTE TEST CONDUCTED ON BEACH POINT  
BUFFERED (pH  $\approx$ 7) GROUNDWATER (WELL CC-33B)  
(TEST NO. 4)

Test Method:	Rotifer Toxkit™ Screening Test (Bio-Response Systems, Halifax, Nova Scotia)
Type of Test:	Static
Date:	December 1-2, 1993
Investigator:	S. D. Turley
Laboratory:	UMD/WREC
Groundwater:	
Source:	APG-EA Beach Point Well CC-33B
Chemical Characteristics:	See Appendix 48
Test Medium:	Rotifer Toxkit™ synthetic medium
Test Organism:	
Scientific Name:	<u>Brachionus rubens</u>
Age at Start of Test:	<4 h after hatch
Source:	Rotifer Toxkit™ cyst
Experimental Chambers:	
Material:	Glass Petri dish
Test Solution Volume:	10 mL
No. Organisms/Replicate:	10
No. Organisms/Treatment:	30
Loading:	n/a
Lighting:	Fluorescent; 60-85 foot candles
Aeration:	None
pH Buffer:	10 N NaOH
Endpoint:	Mortality

## Water Quality:

Dissolved Oxygen (mg/L):	Mean: 8.4 Range: 8.1-8.8 APHA Standards Methods (1989)
pH (std. units):	Mean: 7.3 Range: 7.1-7.6 APHA Standards Methods (1989)
Conductivity ( $\mu$ mhos/cm):	APG-EA diluent water: 190 100% groundwater: 1800 APHA Standards Methods (1989)
Alkalinity (mg/L as $\text{CaCO}_3$ ):	APG-EA diluent water: 50 100% groundwater: 60 APHA Standards Methods (1989)
Hardness (mg/L as $\text{CaCO}_3$ ):	APG-EA diluent water: 50 100% groundwater: 198 APHA Standards Methods (1989)
Temperature ( $^{\circ}\text{C}$ ):	25 $\pm$ 0.5

---

## Results:

The buffered groundwater did not affect rotifer survival.  
The data are summarized in Table A10-1.

TABLE A10-1. ROTIFER BEACH POINT BUFFERED GROUNDWATER TOXICITY  
TEST DATA (TEST NO. 4) - SURVIVAL AFTER 24 HOURS OF  
EXPOSURE

Concentration (% by Volume)	Rep	Number Tested	No. Alive at End of Test	Percent Alive
Growth Medium	1	10	10	100
	2	10	9	90
	3	10	10	100
10	1	10	9	90
	2	10	10	100
	3	10	10	100
18	1	10	10	100
	2	10	10	100
	3	10	10	100
32	1	10	9	90
	2	10	10	100
	3	10	10	100
56	1	10	8	80
	2	10	9	90
	3	10	10	100
100	1	10	7	70
	2	10	9	90
	3	10	8	80

## APPENDIX 11

### GREEN ALGAL 96-H GROWTH TEST CONDUCTED ON BEACH POINT RAW (pH $\approx$ 4) GROUNDWATER (WELL CC-33B) (TEST NO. 1)

Test Method: EPA/600/4-89/001  
(Weber et al., 1989)

Type of Test: Static

Date: April 10-14, 1993

Investigator: S. D. Turley

Laboratory: UMD/WREC

Groundwater:

Source: APG-EA Beach Point Well CC-33B  
Chemical Characteristics: See Appendix 48

Test Medium: Double strength "AAP" medium  
(Miller et al., 1978) with P  
added to achieve a 20:1 N:P  
atomic ratio

Test Organism:

Scientific Name: Selenastrum capricornutum  
Age at Start of Test: Log growth  
Source: UMD/WREC culture

Experimental Chambers:

Material: 250 mL glass culture flasks  
with cheesecloth/cotton  
stoppers

Test Solution Volume: 100 mL

Initial Cell Density:  $1 \times 10^4$  cells/mL

No. Replicates per Treatment: 3

Lighting: Fluorescent; cool white;  
continuous;  $\approx$ 300 foot candles

Shaking Rate: 100 cpm continuously

Endpoint: Reduction in growth relative  
to control



Temperature:

25 ± 0.2 °C

---

Results:

100% raw Beach Point groundwater killed all algal cells during the first 24 h of exposure (Table A11-1). Growth (cell density) was not affected by exposure to concentrations up to 56% raw groundwater by volume (see Tables A11-1 and A11-2). The NOEC and LOEC for reduction in growth are as follows:

NOEC = 56% raw groundwater by volume.

LOEC = 100% raw groundwater by volume.

The 96-h EC50 (reduction in growth), which was determined by the moving average angle method, is as follows:

96-h EC50 = 59.4% raw groundwater by volume (95% confidence limits = 57.01-61.86).

TABLE A11-1. GREEN ALGA BEACH POINT RAW GROUNDWATER TOXICITY  
DATA (TEST NO. 1) - MEAN CELL DENSITY (CELLS/ML)  
AFTER 96 HOURS OF EXPOSURE

Conc (% by Vol)	Rep	Mean Cell Density				
		0H	24H	48H	72H	96H
Growth Medium	1	10120	60120	328400	866210	1333333
	2	10120	64240	341080	828800	1482400
	3	10120	63180	336080	808640	1480400
APG-EA Diluent Water	1	10320	62000	325000	820200	1320000
	2	10320	65200	341300	822800	1510000
	3	10320	60020	333333	811100	1453200
10	1	10430	61000	339020	816400	1395000
	2	10430	64180	327800	802120	1341400
	3	10430	59300	331400	808300	1380800
18	1	10000	62340	348000	820140	1404100
	2	10000	62000	326200	798000	1290900
	3	10000	60040	330120	804600	1320400
32	1	10480	63220	336120	818800	1330360
	2	10480	61040	330080	810100	1288200
	3	10480	60080	340000	820800	1380400
56	1	9900	58600	326800	798800	1278000
	2	9900	59800	322600	790400	1299200
	3	9900	57960	330140	812200	1268200
100	1	10120	DEAD			
	2	10120	DEAD			
	3	10120	DEAD			

Table A11-2. GREEN ALGA BEACH POINT RAW GROUNDWATER TOXICITY  
TEST STATISTICAL ANALYSIS (TEST NO. 1) - MEAN CELL  
DENSITY (CELLS/ML)<sup>a</sup>

---

Data Transformation:

None

Chi-Square Test for Normality:

Calculated test statistic:	5.15
Alpha value:	0.01
Critical value:	13.28
Conclusion:	Fail to reject the null hypothesis that the data are normally distributed

Bartlett's Test for Homogeneity of Variances:

Calculated test statistic:	5.99
Alpha value:	0.01
Critical value:	15.09
Conclusion:	Fail to reject the null hypothesis that the variances are homogenous

ANOVA:

Calculated test statistic:	2.63
Alpha value:	0.05
Critical value:	3.11
Conclusion:	Fail to reject the null hypothesis that all groups are equal

---

<sup>a</sup> The 100% raw Beach Point groundwater treatment was not included in the statistical analyses because all cells died during the test.

## APPENDIX 12

### GREEN ALGAL 96-H GROWTH TEST CONDUCTED ON BEACH POINT BUFFERED (pH $\approx$ 7) GROUNDWATER (WELL CC-33B) (TEST NO. 1)

Test Method: EPA/600/4-89/001  
(Weber et al., 1989)

Type of Test: Static

Date: April 10-14, 1993

Investigator: S. D. Turley

Laboratory: UMD/WREC

Groundwater:

Source: APG-EA Beach Point Well CC-33B  
Chemical Characteristics: See Appendix 48

Test Medium: Double strength "AAP" medium  
(Miller et al., 1978) with P  
added to achieve a 20:1 N:P  
atomic ratio

Test Organism:

Scientific Name: Selenastrum capricornutum  
Age at Start of Test: Log growth  
Source: UMD/WREC culture

Experimental Chambers:

Material: 250 mL glass culture flasks  
with cheesecloth/cotton  
stoppers

Test Solution Volume: 100 mL

Initial Cell Density:  $1 \times 10^4$  cells/mL

No. Replicates per Treatment: 3

Lighting: Fluorescent; cool white;  
continuous;  $\approx$ 300 foot candles

Shaking Rate: 100 cpm continuously

pH Buffer: 10 N NaOH

Endpoint: Reduction in growth relative

to control

Temperature:

25  $\pm$  0.2 °C

---

Results:

Significant ( $\alpha = 0.05$ ) reductions in growth (cell density) occurred in 100% buffered Beach Point groundwater (see Tables A12-1, A12-2 and A12-3). Growth was not affected by exposure to concentrations up to 56% buffered groundwater by volume. The NOEC and LOEC for reduction in growth are as follows:

NOEC = 56% buffered groundwater by volume.  
LOEC = 100% buffered groundwater by volume.

A 96-h EC50 (reduction in growth) could not be calculated because <50% inhibition of growth occurred in the test.

Table A12-1. GREEN ALGA BEACH POINT BUFFERED GROUNDWATER  
TOXICITY DATA (TEST NO. 1) - MEAN CELL DENSITY  
(CELLS/ML) AFTER 96 HOURS OF EXPOSURE

Conc (% by Vol)	Rep	Mean Cell Density				
		0H	24H	48H	72H	96H
Growth Medium	1	10120	60120	328400	814000	1333333
	2	10120	64240	341080	828800	1482400
	3	10120	63180	336080	808640	1480400
32	1	10560	61120	340000	822600	1399300
	2	10560	58400	330860	806200	1326940
	3	10560	60200	333120	810200	1352200
56	1	10600	59980	328760	812200	1340000
	2	10600	59120	341080	826400	1394400
	3	10600	61120	324800	788800	1290460
100	1	10040	58680	318800	786240	1246400
	2	10040	59980	330600	818100	1258800
	3	10040	60120	326420	800800	1300300

Table A12-2. GREEN ALGA BEACH POINT BUFFERED GROUNDWATER  
TOXICITY TEST STATISTICAL ANALYSIS (TEST NO. 1) -  
MEAN CELL DENSITY (CELLS/ML)

---

Data Transformation:

None

Chi-Square Test for Normality:

Calculated test statistic:	4.08
Alpha value:	0.01
Critical value:	13.28
Conclusion:	Fail to reject the null hypothesis that the data are normally distributed

Bartlett's Test for Homogeneity of Variance:

Calculated test statistic:	2.30
Alpha value:	0.01
Critical value:	11.34
Conclusion:	Fail to reject the null hypothesis that the variances are homogenous

ANOVA:

Calculated test statistic:	4.45
Alpha value:	0.05
Critical value:	4.07
Conclusion:	Reject the null hypothesis that all groups are equal

Dunnett's Test:

Calculated test statistic:	See Table A12-3
Alpha value:	0.05
Critical value:	2.42
Conclusion:	Reject the null hypothesis that all groups are equal

---

TABLE A12-3. GREEN ALGA BEACH POINT BUFFERED GROUNDWATER  
TOXICITY TEST STATISTICAL ANALYSIS (TEST NO. 1) -  
RESULTS OF DUNNETT'S TEST ON MEAN CELL DENSITY  
(CELLS/ML)

Conc (% by Vol)	No. of Reps	Mean Cell Density	T Statistic	Significance
Growth Medium	3	1432044		
32	3	1359480	1.61	
56	3	1341620	2.01	
100	3	1268500	3.63	*

\* Significantly different at alpha = 0.05 (Dunnett's critical value = 2.42).



## APPENDIX 13

### GREEN ALGAL 96-H GROWTH TEST CONDUCTED ON BEACH POINT RAW (pH $\approx$ 4) GROUNDWATER (WELL CC-33B) (TEST NO. 2)

Test Method:	EPA/600/4-89/001 (Weber et al., 1989)
Type of Test:	Static
Date:	June 3-7, 1993
Investigator:	S. D. Turley
Laboratory:	UMD/WREC
Groundwater:	
Source:	APG-EA Beach Point Well CC-33B
Chemical Characteristics:	See Appendix 48
Test Medium:	Double strength "AAP" medium (Miller et al., 1978) with P added to achieve a 20:1 N:P atomic ratio
Test Organism:	
Scientific Name:	<u>Selenastrum capricornutum</u>
Age at Start of Test:	Log growth
Source:	UMD/WREC culture
Experimental Chambers:	
Material:	250 mL glass culture flasks with cheesecloth/cotton stoppers
Test Solution Volume:	100 mL
Initial Cell Density:	$1 \times 10^4$ cells/mL
No. Replicates per Treatment:	3
Lighting:	Fluorescent; cool white; continuous; $\approx$ 300 foot candles
Shaking Rate:	100 cpm continuously
Endpoint:	Reduction in growth relative to control

Temperature:

25 ± 0.2 °C

---

Results:

100% raw Beach Point groundwater killed all algal cells during the first 24 h of exposure (Table A13-1). A significant ( $\alpha = 0.05$ ) reduction in cell density occurred in algae exposed to 32% and 56% raw groundwater by volume (see Tables A13-1, A13-2 and A13-3). The NOEC and LOEC for reduction in algal growth are as follows:

NOEC = 18% raw groundwater by volume.

LOEC = 32% raw groundwater by volume.

The 96-h EC50 (reduction in growth), which was determined by the moving average angle method, is as follows:

96-h EC50 = 51.3% raw groundwater by volume (95% confidence limits = 45.15-58.19).

TABLE A13-1. GREEN ALGA BEACH POINT RAW GROUNDWATER TOXICITY  
DATA (TEST NO. 2) - MEAN CELL DENSITY (CELLS/ML)  
AFTER 96 HOURS OF EXPOSURE

Conc (% by Vol)	Rep	Mean Cell Density				
		0H	24H	48H	72H	96H
Growth Medium	1	9880	56500	313200	788880	1369800
	2	9880	59480	309980	791140	1371640
	3	9880	54980	315420	800000	1402760
APG-EA Diluent Water	1	10400	57780	315800	801160	1409400
	2	10400	55560	310400	780080	1359480
	3	10400	56120	313600	790100	1376600
10	1	9920	60080	318000	781400	1359600
	2	9920	55000	309600	789860	1381640
	3	9920	54120	307980	761480	1363300
18	1	10120	58880	311120	780420	1363420
	2	10120	51600	304880	769920	1349120
	3	10120	59400	315580	784240	1372480
32	1	10300	51110	309400	788120	1240800
	2	10300	51940	299980	741760	1190980
	3	10300	53680	307340	760740	1209980
56	1	11000	47420	286124	639560	980880
	2	11000	44800	251160	618540	926140
	3	11000	50120	270280	630680	950460
100	1	10320	DEAD			
	2	10320	DEAD			
	3	10320	DEAD			

Table A13-2. GREEN ALGA BEACH POINT RAW GROUNDWATER TOXICITY  
TEST STATISTICAL ANALYSIS (TEST NO. 2) - MEAN CELL  
DENSITY (CELLS/ML)<sup>a</sup>

---

Data Transformation:

None

Chi-Square Test for Normality:

Calculated test statistic:	5.15
Alpha value:	0.01
Critical value:	13.28
Conclusion:	Fail to reject the null hypothesis that the data are normally distributed

Bartlett's Test for Homogeneity of Variances:

Calculated test statistic:	2.17
Alpha value:	0.01
Critical value:	15.09
Conclusion:	Fail to reject the null hypothesis that the variances are homogenous

ANOVA:

Calculated test statistic:	199.31
Alpha value:	0.05
Critical value:	3.11
Conclusion:	Reject the null hypothesis that all groups are equal

Dunnett's Test:

Calculated test statistic:	See Table A13-3
Alpha value:	0.05
Critical value:	2.50
Conclusion:	Reject the null hypothesis that all groups are equal

---

<sup>a</sup> The 100% raw Beach Point groundwater treatment was not included in the statistical analyses because all cells died during the test.

Table A13-3. GREEN ALGA BEACH POINT RAW GROUNDWATER TOXICITY  
TEST STATISTICAL ANALYSIS (TEST NO. 2) - RESULTS OF  
DUNNETT'S TEST ON MEAN CELL DENSITY (CELLS/ML)

Conc (% by Vol)	No. of Reps	Mean Cell Density	T Statistic	Significance
Growth Medium	3	1381400		
APG-EA Diluent Water	3	1381827	-0.03	
10	3	1368180	0.77	
18	3	1361673	1.15	
32	3	1213920	9.76	*
56	3	952493	25.00	*

\* Significantly different at  $\alpha = 0.05$  (Dunnett's critical  
value = 2.50).

## APPENDIX 14

### GREEN ALGAL 96-H GROWTH TEST CONDUCTED ON BEACH POINT BUFFERED (pH $\approx$ 7) GROUNDWATER (WELL CC-33B) (TEST NO. 2)

Test Method:	EPA/600/4-89/001 (Weber et al., 1989)
Type of Test:	Static
Date:	June 3-7, 1993
Investigator:	S. D. Turley
Laboratory:	UMD/WREC
Groundwater:	
Source:	APG-EA Beach Point Well CC-33B
Chemical Characteristics:	See Appendix 48
Test Medium:	Double strength "AAP" medium (Miller et al., 1978) with P added to achieve a 20:1 N:P atomic ratio
Test Organism:	
Scientific Name:	<u>Selenastrum capricornutum</u>
Age at Start of Test:	Log growth
Source:	UMD/WREC culture
Experimental Chambers:	
Material:	250 mL glass culture flasks with cheesecloth/cotton stoppers
Test Solution Volume:	100 mL
Initial Cell Density:	$1 \times 10^4$ cells/mL
No. Replicates per Treatment:	3
Lighting:	Fluorescent; cool white; continuous; $\approx$ 300 foot candles
Shaking Rate:	100 cpm continuously
pH Buffer:	10 N NaOH
Endpoint:	Reduction in growth relative

to control

Temperature:

25  $\pm$  0.2 °C

---

Results:

100% buffered Beach Point groundwater killed all algal cells during the first 24 h of exposure (see Table A14-1). A significant ( $\alpha = 0.05$ ) reduction in cell density occurred in algae exposed to 56% buffered groundwater by volume (see Tables A14-1, A14-2 and A14-3). The NOEC and LOEC for reduction in growth are as follows:

NOEC = 32% buffered groundwater by volume.

LOEC = 56% buffered groundwater by volume.

The 96-h EC50 (reduction in growth), which was determined by the moving average angle method, is as follows:

96-h EC50 = 58.2% raw groundwater by volume (95% confidence limits = 55.81-60.70).

Table A14-1. GREEN ALGA BEACH POINT BUFFERED GROUNDWATER  
TOXICITY DATA (TEST NO. 2) - MEAN CELL DENSITY  
(CELLS/ML) AFTER 96 HOURS OF EXPOSURE

Conc (% by Vol)	Rep	Mean Cell Density				
		0H	24H	48H	72H	96H
Growth Medium	1	9880	56500	313200	788880	1369800
	2	9880	59480	309980	791140	1371640
	3	9880	54980	315420	800000	1402760
32	1	10600	56500	316600	779690	1360340
	2	10600	57980	317700	784600	1379960
	3	10600	54000	304880	759980	1359980
56	1	11200	50000	281460	638080	960840
	2	11200	48640	260480	627580	919860
	3	11200	52180	290100	649590	1000800
100	1	10040	DEAD			
	2	10040	DEAD			
	3	10040	DEAD			



Table A14-2. GREEN ALGA BEACH POINT BUFFERED GROUNDWATER  
TOXICITY TEST STATISTICAL ANALYSIS (TEST NO. 2) -  
MEAN CELL DENSITY (CELLS/ML)<sup>a</sup>

---

Data Transformation:

None

Chi-Square Test for Normality:

Calculated test statistic:	6.90
Alpha value:	0.01
Critical value:	13.28
Conclusion:	Fail to reject the null hypothesis that the data are normally distributed

Bartlett's Test for Homogeneity of Variance:

Calculated test statistic:	2.55
Alpha value:	0.01
Critical value:	9.21
Conclusion:	Fail to reject the null hypothesis that the variances are homogenous

ANOVA:

Calculated test statistic:	243.24
Alpha value:	0.05
Critical value:	5.14
Conclusion:	Reject the null hypothesis that all groups are equal

Dunnett's Test:

Calculated test statistic:	See Table A14-3
Alpha value:	0.05
Critical value:	2.34
Conclusion:	Reject the null hypothesis that all groups are equal

---

<sup>a</sup> The 100% buffered Beach Point groundwater treatment was not included in the statistical analyses because all cells died during the test.

TABLE A14-3. GREEN ALGA BEACH POINT BUFFERED GROUNDWATER  
TOXICITY TEST STATISTICAL ANALYSIS (TEST NO. 2) -  
RESULTS OF DUNNETT'S TEST ON MEAN CELL DENSITY  
(CELLS/ML)

Conc (% by Vol)	No. of Reps	Mean Cell Density	T Statistic	Significance
Growth Medium	3	1381400		
32	3	1366760	0.68	
56	3	960500	19.43	*

\* Significantly different at  $\alpha = 0.05$  (Dunnett's critical value = 2.34).

APPENDIX 15

GREEN ALGAL 96-H GROWTH TEST CONDUCTED ON BEACH  
POINT RAW (pH  $\approx$ 4) GROUNDWATER (WELL CC-33B)  
(TEST NO. 3)

Test Method: EPA/600/4-89/001  
(Weber et al., 1989)

Type of Test: Static

Date: August 24-28, 1993

Investigator: S. D. Turley

Laboratory: UMD/WREC

Groundwater:

Source: APG-EA Beach Point Well CC-33B  
Chemical Characteristics: See Appendix 48

Test Medium: Double strength "AAP" medium  
(Miller et al., 1978) with P  
added to achieve a 20:1 N:P  
atomic ratio

Test Organism:

Scientific Name: Selenastrum capricornutum  
Age at Start of Test: Log growth  
Source: UMD/WREC culture

Experimental Chambers:

Material: 250 mL glass culture flasks  
with cheesecloth/cotton  
stoppers

Test Solution Volume: 100 mL

Initial Cell Density:  $1 \times 10^4$  cells/mL

No. Replicates per Treatment: 3

Lighting: Fluorescent; cool white;  
continuous;  $\approx$ 300 foot candles

Shaking Rate: 100 cpm continuously

Endpoint: Reduction in growth relative  
to control

Temperature:

25 ± 0.2 °C

---

Results:

100% raw Beach Point groundwater killed all algal cells during the first 24 h of exposure (Table A15-1). A significant ( $\alpha = 0.05$ ) reduction in cell density occurred in algae exposed to 32% and 56% raw groundwater by volume (see Tables A15-1, A15-2 and A15-3). The NOEC and LOEC for reduction in growth are as follows:

NOEC = 18% raw groundwater by volume.

LOEC = 32% raw groundwater by volume.

The 96-h EC50 (reduction in growth), which was determined by the moving average angle method, is as follows:

96-h EC50 = 56.5% raw groundwater by volume (95% confidence limits = 54.04-59.04).

TABLE A15-1. GREEN ALGA BEACH POINT RAW GROUNDWATER TOXICITY  
DATA (TEST NO. 3) - MEAN CELL DENSITY (CELLS/ML)  
AFTER 96 HOURS OF EXPOSURE

Conc (% by Vol)	Rep	Mean Cell Density				
		0H	24H	48H	72H	96H
Growth Medium	1	10100	51900	278100	681040	1182860
	2	10100	54800	259880	666460	1159680
	3	10100	57950	267140	670680	1176840
APG-EA Diluent Water	1	10400	55000	270080	680080	1180000
	2	10400	49600	255840	659980	1157980
	3	10400	53480	259480	669840	1173640
10	1	9900	52400	272280	655780	1159180
	2	9900	49580	270140	667740	1169240
	3	9900	53980	256420	650640	1146140
18	1	10000	50000	251480	653880	1143640
	2	10000	49860	263640	661880	1147160
	3	10000	54380	269120	666360	1167260
32	1	11000	52000	264400	646680	1137640
	2	11000	51040	260080	629860	1107480
	3	11000	53460	267460	634980	1118240
56	1	10800	45080	232000	550840	820140
	2	10800	48600	238200	541000	804400
	3	10800	44320	229480	505080	775180
100	1	10800	DEAD			
	2	10800	DEAD			
	3	10800	DEAD			

Table A15-2. GREEN ALGA BEACH POINT RAW GROUNDWATER TOXICITY  
TEST STATISTICAL ANALYSIS (TEST NO. 3) - MEAN CELL  
DENSITY (CELLS/ML)<sup>a</sup>

---

Data Transformation:

None

Chi-Square Test for Normality:

Calculated test statistic:	3.76
Alpha value:	0.01
Critical value:	13.28
Conclusion:	Fail to reject the null hypothesis that the data are normally distributed

Bartlett's Test for Homogeneity of Variances:

Calculated test statistic:	1.42
Alpha value:	0.01
Critical value:	15.09
Conclusion:	Fail to reject the null hypothesis that the variances are homogenous

ANOVA:

Calculated test statistic:	290.41
Alpha value:	0.05
Critical value:	3.11
Conclusion:	Reject the null hypothesis that all groups are equal

Dunnett's Test:

Calculated test statistic:	See Table A15-3
Alpha value:	0.05
Critical value:	2.50
Conclusion:	Reject the null hypothesis that all groups are equal

---

<sup>a</sup> The 100% raw Beach Point groundwater treatment was not included in the statistical analyses because all cells died during the test.

Table A15-3. GREEN ALGA BEACH POINT RAW GROUNDWATER TOXICITY  
TEST STATISTICAL ANALYSIS (TEST NO. 3) - RESULTS OF  
DUNNETT'S TEST ON MEAN CELL DENSITY (CELLS/ML)

Conc (% by Vol)	No. of Reps	Mean Cell Density	T Statistic	Significance
Growth Medium	3	1173127		
APG-EA Diluent Water	3	1170480	0.218	
10	3	1158187	1.231	
18	3	1152627	1.690	
32	3	1121120	4.286	*
56	3	799907	30.761	*

\* Significantly different at alpha = 0.05 (Dunnett's critical  
value = 2.50).

## APPENDIX 16

### GREEN ALGAL 96-H GROWTH TEST CONDUCTED ON BEACH POINT BUFFERED (pH $\approx$ 7) GROUNDWATER (WELL CC-33B) (TEST NO. 3)

Test Method: EPA/600/4-89/001  
(Weber et al., 1989)

Type of Test: Static

Date: August 24-28, 1993

Investigator: S. D. Turley

Laboratory: UMD/WREC

Groundwater:

Source: APG-EA Beach Point Well CC-33B  
Chemical Characteristics: See Appendix 48

Test Medium: Double strength "AAP" medium  
(Miller et al., 1978) with P  
added to achieve a 20:1 N:P  
atomic ratio

Test Organism:

Scientific Name: Selenastrum capricornutum  
Age at Start of Test: Log growth  
Source: UMD/WREC culture

Experimental Chambers:

Material: 250 mL glass culture flasks  
with cheesecloth/cotton  
stoppers

Test Solution Volume: 100 mL

Initial Cell Density:  $1 \times 10^4$  cells/mL

No. Replicates per Treatment: 3

Lighting: Fluorescent; cool white;  
continuous;  $\approx$ 300 foot candles

Shaking Rate: 100 cpm continuously

pH Buffer: 10 N NaOH



Endpoint: Reduction in growth relative  
to control

Temperature: 25 ± 0.2 °C

---

Results:

100% buffered Beach Point groundwater killed all algal cells during the first 24 h of exposure (Table A16-1). A significant ( $\alpha = 0.05$ ) reduction in cell density occurred in algae exposed to 32% and 56% raw groundwater by volume (see Tables A16-1, A16-2 and A16-3). The NOEC and LOEC for reduction in growth are as follows:

NOEC = 18% buffered groundwater by volume.  
LOEC = 32% buffered groundwater by volume.

The 96-h EC50 (reduction in growth), which was determined by the moving average angle method, is as follows:

96-h EC50 = 54.5% raw groundwater by volume (95% confidence limits = 51.06-58.52).

Table A16-1. GREEN ALGA BEACH POINT BUFFERED GROUNDWATER  
TOXICITY DATA (TEST NO. 3) - MEAN CELL DENSITY  
(CELLS/ML) AFTER 96 HOURS OF EXPOSURE

Conc (% by Vol)	Rep	Mean Cell Density				
		0H	24H	48H	72H	96H
Growth Medium	1	10100	51900	278100	681040	1182860
	2	10100	54800	259880	666460	1159680
	3	10100	57950	267140	670680	1176840
18	1	10500	55480	270120	670000	1160580
	2	10500	51640	264120	663020	1155440
	3	10500	52860	261440	659860	1147640
32	1	10100	54800	251240	636460	1119080
	2	10100	50860	245240	619960	1097680
	3	10100	51000	251660	627680	1106980
56	1	10300	46880	230420	535400	805140
	2	10300	41640	209400	470840	714980
	3	10300	43640	222980	459240	702140
100	1	9800	DEAD			
	2	9800	DEAD			
	3	9800	DEAD			

Table A16-2. GREEN ALGA BEACH POINT BUFFERED GROUNDWATER  
TOXICITY TEST STATISTICAL ANALYSIS (TEST NO. 3) -  
MEAN CELL DENSITY (CELLS/ML)<sup>a</sup>

---

Data Transformation:

None

Chi-Square Test for Normality:

Calculated test statistic:	2.51
Alpha value:	0.01
Critical value:	13.28
Conclusion:	Fail to reject the null hypothesis that the data are normally distributed

Bartlett's Test for Homogeneity of Variance:

Calculated test statistic:	9.13
Alpha value:	0.01
Critical value:	11.34
Conclusion:	Fail to reject the null hypothesis that the variances are homogenous

ANOVA:

Calculated test statistic:	144.74
Alpha value:	0.05
Critical value:	4.07
Conclusion:	Reject the null hypothesis that all groups are equal

Dunnett's Test:

Calculated test statistic:	See Table A16-3
Alpha value:	0.05
Critical value:	2.42
Conclusion:	Reject the null hypothesis that all groups are equal

---

<sup>a</sup> The 100% buffered Beach Point groundwater treatment was not included in the statistical analyses because all cells died during the test.

TABLE A16-3. GREEN ALGA BEACH POINT BUFFERED GROUNDWATER  
TOXICITY TEST STATISTICAL ANALYSIS (TEST NO. 3) -  
RESULTS OF DUNNETT'S TEST ON MEAN CELL DENSITY  
(CELLS/ML)

Conc (% by Vol)	No. of Reps	Mean Cell Density	T Statistic	Significance
Growth Medium	3	1173127		
18	3	1154553	0.774	
32	3	1107913	2.719	*
56	3	740753	18.024	*

\* Significantly different at alpha = 0.05 (Dunnett's critical  
value = 2.47).

## APPENDIX 17

### GREEN ALGAL 96-H GROWTH TEST CONDUCTED ON BEACH POINT RAW (pH $\approx$ 4) GROUNDWATER (WELL CC-33B) (TEST NO. 4)

Test Method:	EPA/600/4-89/001 (Weber et al., 1989)
Type of Test:	Static
Date:	December 1-5, 1993
Investigator:	S. D. Turley
Laboratory:	UMD/WREC
Groundwater:	
Source:	APG-EA Beach Point Well CC-33B
Chemical Characteristics:	See Appendix 48
Test Medium:	Double strength "AAP" medium (Miller et al., 1978) with P added to achieve a 20:1 N:P atomic ratio
Test Organism:	
Scientific Name:	<u>Selenastrum capricornutum</u>
Age at Start of Test:	Log growth
Source:	UMD/WREC culture
Experimental Chambers:	
Material:	250 mL glass culture flasks with cheesecloth/cotton stoppers
Test Solution Volume:	100 mL
Initial Cell Density:	$1 \times 10^4$ cells/mL
No. Replicates per Treatment:	3
Lighting:	Fluorescent; cool white; continuous; $\approx$ 300 foot candles
Shaking Rate:	100 cpm continuously
Endpoint:	Reduction in growth relative to control

Temperature:

25 ± 0.2 °C

---

Results:

100% raw Beach Point groundwater killed all algal cells during the first 24 h of exposure (Table A17-1). A significant ( $\alpha = 0.05$ ) reduction in cell density occurred in algae exposed to 32% and 56% raw groundwater by volume (see Tables A17-1, A17-2 and A17-3). The NOEC and LOEC for reduction in growth are as follows:

NOEC = 18% raw groundwater by volume.

LOEC = 32% raw groundwater by volume.

The 96-h EC50 (reduction in growth), which was determined by the moving average angle method, is as follows:

96-h EC50 = 54.6% raw groundwater by volume (95% confidence limits = 51.24-58.51).

TABLE A17-1. GREEN ALGA BEACH POINT RAW GROUNDWATER TOXICITY  
DATA (TEST NO. 4) - MEAN CELL DENSITY (CELLS/ML)  
AFTER 96 HOURS OF EXPOSURE

Conc (% by Vol)	Rep	Mean Cell Density				
		0H	24H	48H	72H	96H
Growth Medium	1	10400	66800	270240	570840	1510840
	2	10400	58660	278880	582040	1601000
	3	10400	56660	264660	560220	1496460
APG-EA Diluent Water	1	10600	59880	276880	606800	1580000
	2	10600	59600	265840	579980	1557980
	3	10600	56480	269480	569440	1503440
10	1	10860	70000	288440	590080	1622000
	2	10860	58800	270240	576400	1509460
	3	10860	60240	264240	280260	1501200
18	1	11100	62240	270760	577240	1468960
	2	11100	64200	266240	570200	1555800
	3	11100	66380	260080	560000	1548980
32	1	9880	54980	230880	538080	1380640
	2	9880	55640	241680	550680	1478000
	3	9880	59880	226320	529400	1398240
56	1	12100	50400	200420	486260	999880
	2	12100	55600	222240	499780	1112660
	3	12100	57680	199980	460560	1001240
100	1	10000	DEAD			
	2	10000	DEAD			
	3	10000	DEAD			

Table A17-2. GREEN ALGA BEACH POINT RAW GROUNDWATER TOXICITY  
TEST STATISTICAL ANALYSIS (TEST NO. 4) - MEAN CELL  
DENSITY (CELLS/ML)<sup>a</sup>

---

Data Transformation:

None

Chi-Square Test for Normality:

Calculated test statistic:	9.25
Alpha value:	0.01
Critical value:	13.28
Conclusion:	Fail to reject the null hypothesis that the data are normally distributed

Bartlett's Test for Homogeneity of Variances:

Calculated test statistic:	0.63
Alpha value:	0.01
Critical value:	15.09
Conclusion:	Fail to reject the null hypothesis that the variances are homogenous

ANOVA:

Calculated test statistic:	38.98
Alpha value:	0.05
Critical value:	3.11
Conclusion:	Reject the null hypothesis that all groups are equal

Dunnett's Test:

Calculated test statistic:	See Table A17-3
Alpha value:	0.05
Critical value:	2.50
Conclusion:	Reject the null hypothesis that all groups are equal

---

<sup>a</sup> The 100% raw Beach Point groundwater treatment was not included in the statistical analyses because all cells died during the test.



Table A17-3. GREEN ALGA BEACH POINT RAW GROUNDWATER TOXICITY  
TEST STATISTICAL ANALYSIS (TEST NO. 4) - RESULTS OF  
DUNNETT'S TEST ON MEAN CELL DENSITY (CELLS/ML)

Conc (% by Vol)	No. of Reps	Mean Cell Density	T Statistic	Significance
Growth Medium	3	1536100		
APG-EA Diluent Water	3	1547140	-0.243	
10	3	1544220	-0.179	
18	3	1524580	0.254	
32	3	1418960	2.582	*
56	3	1037927	10.979	*

\* Significantly different at alpha = 0.05 (Dunnett's critical  
value = 2.50).

## APPENDIX 18

### GREEN ALGAL 96-H GROWTH TEST CONDUCTED ON BEACH POINT BUFFERED (pH $\approx$ 7) GROUNDWATER (WELL CC-33B) (TEST NO. 4)

Test Method:	EPA/600/4-89/001 (Weber et al., 1989)
Type of Test:	Static
Date:	December 1-5, 1993
Investigator:	S. D. Turley
Laboratory:	UMD/WREC
Groundwater:	
Source:	APG-EA Beach Point Well CC-33B
Chemical Characteristics:	See Appendix 48
Test Medium:	Double strength "AAP" medium (Miller et al., 1978) with P added to achieve a 20:1 N:P atomic ratio
Test Organism:	
Scientific Name:	<u>Selenastrum capricornutum</u>
Age at Start of Test:	Log growth
Source:	UMD/WREC culture
Experimental Chambers:	
Material:	250 mL glass culture flasks with cheesecloth/cotton stoppers
Test Solution Volume:	100 mL
Initial Cell Density:	$1 \times 10^4$ cells/mL
No. Replicates per Treatment:	3
Lighting:	Fluorescent; cool white; continuous; $\approx$ 300 foot candles
Shaking Rate:	100 cpm continuously
pH Buffer:	10 N NaOH

Endpoint:

Reduction in growth relative  
to control

Temperature:

25 ± 0.2 °C

---

Results:

100% buffered Beach Point groundwater killed all algal cells during the first 24 h of exposure (Table A18-1). A significant ( $\alpha = 0.05$ ) reduction in cell density occurred in algae exposed to 32% and 56% raw groundwater by volume (see Tables A18-1, A18-2 and A18-3). The NOEC and LOEC for reduction in growth are as follows:

NOEC = 18% buffered groundwater by volume.

LOEC = 32% buffered groundwater by volume.

The 96-h EC50 (reduction in growth), which was determined by the moving average angle method, is as follows:

96-h EC50 = 49.7% raw groundwater by volume (95% confidence limits = 46.56-53.22).

Table A18-1. GREEN ALGA BEACH POINT BUFFERED GROUNDWATER  
TOXICITY DATA (TEST NO. 4) - MEAN CELL DENSITY  
(CELLS/ML) AFTER 96 HOURS OF EXPOSURE

Conc (% by Vol)	Rep	Mean Cell Density				
		0H	24H	48H	72H	96H
Growth Medium	1	10400	66800	270240	570840	1510840
	2	10400	58660	278880	582040	1601000
	3	10400	56660	264660	560220	1496460
10	1	10400	63000	254240	555460	1481300
	2	10400	60360	248860	526780	1468340
	3	10400	62760	259980	566960	1444440
18	1	12400	66000	268860	587240	1561000
	2	12400	60780	265660	570240	1460000
	3	12400	57700	260000	548480	1448660
32	1	10420	57000	222300	536240	1219920
	2	10420	59980	209240	538000	1267080
	3	10420	61000	231880	521000	1300480
56	1	9680	50240	196880	451240	898200
	2	9680	58140	190180	455980	918460
	3	9680	59000	189040	425000	953440
100	1	9800	DEAD			
	2	9800	DEAD			
	3	9800	DEAD			

Table A18-2. GREEN ALGA BEACH POINT BUFFERED GROUNDWATER  
TOXICITY TEST STATISTICAL ANALYSIS (TEST NO. 4) -  
MEAN CELL DENSITY (CELLS/ML)<sup>a</sup>

---

Data Transformation:

None

Chi-Square Test for Normality:

Calculated test statistic:	3.13
Alpha value:	0.01
Critical value:	13.28
Conclusion:	Fail to reject the null hypothesis that the data are normally distributed

Bartlett's Test for Homogeneity of Variance:

Calculated test statistic:	2.77
Alpha value:	0.01
Critical value:	13.28
Conclusion:	Fail to reject the null hypothesis that the variances are homogenous

ANOVA:

Calculated test statistic:	97.90
Alpha value:	0.05
Critical value:	3.48
Conclusion:	Reject the null hypothesis that all groups are equal

Dunnett's Test:

Calculated test statistic:	See Table A18-3
Alpha value:	0.05
Critical value:	2.47
Conclusion:	Reject the null hypothesis that all groups are equal

---

<sup>a</sup> The 100% buffered Beach Point groundwater treatment was not included in the statistical analyses because all cells died during the test.

TABLE A18-3. GREEN ALGA BEACH POINT BUFFERED GROUNDWATER  
TOXICITY TEST STATISTICAL ANALYSIS (TEST NO. 4) -  
RESULTS OF DUNNETT'S TEST ON MEAN CELL DENSITY  
(CELLS/ML)

Conc (% by Vol)	No. of Reps	Mean Cell Density	T Statistic	Significance
Growth Medium	3	1536100		
10	3	1464693	1.975	
18	3	1489887	1.278	
32	3	1262493	7.567	*
56	3	923367	16.947	*

\* Significantly different at alpha = 0.05 (Dunnett's critical  
value = 2.47).

APPENDIX 19

CLADOCERAN ACUTE AND 7-DAY SURVIVAL AND REPRODUCTION  
TEST CONDUCTED ON BEACH POINT RAW (pH  $\approx$ 4)  
GROUNDWATER (WELL CC-33B)  
(TEST NO. 1)

Test Method:	EPA/600/4-89/001 (Weber et al., 1989)
Type of Test:	Static renewal (every 24 h)
Date:	April 7-14, 1993
Investigator:	S.D. Turley
Laboratory:	UMD/WREC
Groundwater:	
Source:	APG-EA Beach Point Well CC-33B
Chemical Characteristics:	See Appendix 48
Dilution Water:	
Source:	20% Perrier: 80% RO water
Chemical Characteristics:	See Table A19-1
Test Organism:	
Scientific Name:	<u>Ceriodaphnia dubia</u>
Age at Start of Test:	<4 h
Source:	UMD/WREC culture
Experimental Chambers:	
Material:	50 mL glass beaker
Test Solution Volume:	25 mL
No. Organisms/Replicate:	1
No. Organisms/Treatment:	10
Loading:	1 organism/beaker
Lighting:	Fluorescent; 60-85 foot candles
Aeration:	Prior to each renewal

Endpoints:

Mortality of adults; number of neonates produced in 3 broods

Water Quality:

Table A19-1

---

Results:

Mortality:

48-h Exposure:

The data for the 48-h LC50 were obtained from the 7-d study. All organisms exposed to 100% raw groundwater died during the 48-h exposure (Table A19-2). The organisms in all other treatments lived. The 48-h LC50, which was determined by the moving average angle method, is as follows:

48-h LC50 = 64.7% raw groundwater by volume (95% confidence limits = 57.17-75.48).

7-d Exposure:

All organisms exposed to 100% raw groundwater died during the 7-d exposure (Table A19-3); organisms in all other treatments lived. The 7-d LC50, which was determined by the moving average angle method, is as follows:

7-d LC50 = 64.7% raw groundwater by volume (95% confidence limits = 57.17-75.48).

Neonate Production:

Raw groundwater significantly ( $\alpha = 0.05$ ) reduced neonate production relative to the controls down to 32% raw groundwater by volume (see Tables A19-3, A19-4, and A19-5). The NOEC and LOEC for the daphnids, based on reduced neonate production, are as follows:

NOEC = 18% raw groundwater by volume.

LOEC = 32% raw groundwater by volume.



TABLE A19-1. SUMMARY OF THE BEACH POINT RAW GROUNDWATER BIOASSAY  
WATER QUALITY DATA FOR THE CLADOCERAN 7-DAY TEST  
(TEST NO. 1) - DISSOLVED OXYGEN (MG/L)

<u>Test Concentrations (Percent Groundwater by Volume)</u>						
	0	10	18	32	56	100
<u>Day 0</u>						
0 H	8.8	8.7	8.6	8.3	8.2	8.2
<u>Day 1</u>						
0 H	8.2	8.1	8.1	8.1	8.1	5.6
24 H	8.1	8.1	8.1	7.8	7.8	
<u>Day 2</u>						
0 H	8.2	8.1	8.1	8.1	8.1	
24 H	7.6	7.6	7.6	7.6	7.6	
<u>Day 3</u>						
0 H	8.4	8.2	8.1	8.2	8.1	
24 H	7.6	7.5	7.5	7.5	7.5	
<u>Day 4</u>						
0 H	8.4	8.2	8.2	8.2	8.0	
24 H	8.5	8.5	8.6	8.6	8.6	
<u>Day 5</u>						
0 H	8.3	8.3	8.3	8.1	8.1	
24 H	8.5	8.4	8.4	8.5	8.5	
<u>Day 6</u>						
0 H	8.5	8.1	8.2	8.0	8.0	
24 H	8.4	8.2	8.4	8.6	8.6	
<u>Day 7</u>						
24 H	8.1	8.2	8.1	8.1	8.1	

TABLE A19-1. (CONTINUED) - pH (STANDARD UNITS)

	<u>Test Concentrations (Percent Groundwater by Volume)</u>					
	0	10	18	32	56	100
<u>Day 0</u>						
0 H	6.83	6.81	6.81	6.71	5.93	3.93
<u>Day 1</u>						
0 H	6.68	6.77	6.81	6.70	6.84	3.74
24 H	6.63	6.81	6.98	6.80	6.72	
<u>Day 2</u>						
0 H	6.75	6.79	6.82	6.77	6.26	
24 H	6.52	6.71	6.91	7.02	7.08	
<u>Day 3</u>						
0 H	6.69	6.32	6.28	6.27	6.23	
24 H	6.57	6.51	6.61	6.78	6.80	
<u>Day 4</u>						
0 H	6.49	6.61	6.64	6.62	6.56	
24 H	6.38	6.53	6.67	6.82	6.91	
<u>Day 5</u>						
0 H	7.00	7.07	6.93	6.63	6.17	
24 H	7.04	6.99	7.03	7.10	7.11	
<u>Day 6</u>						
0 H	7.03	6.99	6.88	6.71	6.28	
24 H	7.09	6.87	7.01	7.01	7.00	
<u>Day 7</u>						
24 H	6.71	6.74	6.87	6.92	6.94	

TABLE A19-1. (CONTINUED) - CONDUCTIVITY ( $\mu$ MHOS/CM)

<u>Test Concentrations (Percent Groundwater by Volume)</u>		
	<u>0</u>	<u>100</u>
<u>Day 0</u>		
0 H	140	1500
<u>Day 1</u>		
0 H	170	1600
<u>Day 2</u>		
0 H	155	
<u>Day 3</u>		
0 H	155	
<u>Day 4</u>		
0 H	165	
<u>Day 5</u>		
0 H	160	
<u>Day 6</u>		
0 H	165	
<u>Day 7</u>		
24 H	158	

TABLE A19-1. (CONTINUED) - ALKALINITY (MG/L AS CaCO<sub>3</sub>)

	<u>Test Concentrations (Percent Groundwater by Volume)</u>	
	<u>0</u>	<u>100</u>
<u>Day 0</u>		
0 H	50	<sup>a</sup>
<u>Day 1</u>		
0 H	50	<sup>a</sup>
<u>Day 2</u>		
0 H	50	
<u>Day 3</u>		
0 H	50	
<u>Day 4</u>		
0 H	50	
<u>Day 5</u>		
0 H	50	
<u>Day 6</u>		
0 H	50	
<u>Day 7</u>		
24 H	50	

<sup>a</sup> Could not obtain measurement.

TABLE A19-1. (CONTINUED) - HARDNESS (MG/L AS CaCO<sub>3</sub>)

<u>Test Concentrations (Percent Groundwater by Volume)</u>		
	<u>0</u>	<u>100</u>
<u>Day 0</u>		
0 H	48	a
<u>Day 1</u>		
0 H	46	a
<u>Day 2</u>		
0 H	56	
<u>Day 3</u>		
0 H	50	
<u>Day 4</u>		
0 H	52	
<u>Day 5</u>		
0 H	54	
<u>Day 6</u>		
0 H	54	
<u>Day 7</u>		
24 H	51	

<sup>a</sup> Could not obtain measurement.

TABLE A19-2. CLADOCERAN BEACH POINT RAW GROUNDWATER TOXICITY  
TEST DATA (TEST NO. 1) - SURVIVAL AFTER 48 HOURS OF  
EXPOSURE

Concentration (% Groundwater by Volume)	Number Tested	No. Alive at 48 Hours	Percent Alive
UMD/WREC Control	10	10	100
10	10	10	100
18	10	10	100
32	10	10	100
56	10	10	100
100	10	0	0

TABLE A19-3. CLADOCERAN BEACH POINT RAW GROUNDWATER TOXICITY DATA (TEST NO. 1) - SURVIVAL OF ADULTS, NUMBER OF YOUNG PRODUCED PER BROOD, TOTAL NUMBER OF YOUNG, AND MEAN NUMBER OF YOUNG PER BROOD AFTER 7 DAYS OF EXPOSURE

Conc (% by Vol)	Rep	Brood No. 1	Brood No. 2	Brood No. 3	Total Young	Mean Young Per Brood
UMD/WREC Control	1	6	13	13	32	10.7
	2	4	12	12	28	9.3
	3	7	11	11	29	9.7
	4	4	10	11	25	8.3
	5	3	14	13	30	10.0
	6	5	7	13	25	8.3
	7	7	11	11	29	9.7
	8					
	9	a 4	14	15	33	11.0
	10	5	12	11	28	9.3
APG-EA Diluent Water	1	5	11	12	28	9.3
	2	4	10	13	27	9.0
	3	2	9	14	25	8.3
	4	5	9	14	28	9.3
	5	4	8	12	24	8.0
	6	5	10	11	26	8.7
	7	6	9	12	27	9.0
	8	6	10	11	27	9.0
	9	5	10	13	28	9.3
	10	5	11	15	31	10.3
10	1	7	10	13	30	10.0
	2	7	11	10	28	9.3
	3	6	12	10	28	9.3
	4	6	11	9	26	8.7
	5	5	11	9	25	8.3
	6	7	11	11	29	9.7
	7	4	8	9	21	7.0
	8	7	10	12	29	9.7
	9	5	11	12	28	9.3
	10	7	11	11	29	9.7

TABLE A19-3. (CONTINUED)

Conc (% by Vol)	Rep	Brood No. 1	Brood No. 2	Brood No. 3	Total Young	Mean Young Per Brood
18	1	5	10	8	23	7.7
	2	a				
	3	6	9	8	23	7.7
	4	7	9	10	26	8.7
	5	a				
	6	6	11	12	29	9.7
	7	6	11	12	29	9.7
	8	6	10	10	26	8.7
	9	6	8	10	24	8.0
	10	4	6	11	21	7.0
32	1	7	9	12	28	9.3
	2	7	0	9	16	8.0
	3	5	9	10	24	8.0
	4	6	9	9	24	8.0
	5	6	6	4	16	5.3
	6	4	7	8	19	6.3
	7	7	10	10	27	9.0
	8	6	9	11	26	8.7
	9	5	8	5	18	6.0
	10	6	8	7	21	7.0
56	1	2	3	12	17	5.7
	2	2	4	4	10	3.3
	3	4	3	7	14	4.7
	4	4	6	7	17	5.7
	5	5	9	8	22	7.3
	6	4	6	8	18	6.0
	7	5	6	8	19	6.3
	8	4	5	10	19	6.3
	9	4	4	3	11	3.7
	10	5	5	6	16	5.3



TABLE A19-3. (CONTINUED)

Conc (% by Vol)	Rep	Brood No. 1	Brood No. 2	Brood No. 3	Total Young	Mean Young Per Brood
100	1	DEAD				
	2	DEAD				
	3	DEAD				
	4	DEAD				
	5	DEAD				
	6	DEAD				
	7	DEAD				
	8	DEAD				
	9	DEAD				
	10	DEAD				

<sup>a</sup> Male adult, which was included in survival analysis, was not included in the neonate production analysis.

TABLE A19-4. CLADOCERAN BEACH POINT RAW GROUNDWATER TOXICITY  
TEST STATISTICAL ANALYSIS (TEST NO. 1) - NEONATE  
PRODUCTION AFTER 7 DAYS OF EXPOSURE<sup>a</sup>

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Data Transformation:

None

Chi-square Test for Normality:

Calculated test statistic:	1.07
Alpha value:	0.01
Critical value:	13.28
Conclusion	Fail to reject the null hypothesis that the data are normally distributed

Bartlett's Test for Homogeneity of Variances:

Calculated test statistic:	6.97
Alpha value:	0.01
Critical value:	15.09
Conclusion:	Fail to reject the null hypothesis that the variances are homogenous

ANOVA:

Calculated test statistic:	20.54
Alpha value:	0.05
Critical value:	2.45
Conclusion:	Reject the null hypothesis that all groups are equal

Bonferroni's T-test:

Calculated test statistics:	See Table A19-5
Alpha value:	0.05
Critical value:	2.40
Conclusion:	Reject the null hypothesis that all groups are equal

---

<sup>a</sup> The 100% raw Beach Point groundwater treatment was not included in the statistical analyses because all organisms died during the test.

TABLE A19-5. CLADOCERAN BEACH POINT RAW GROUNDWATER TOXICITY  
TEST STATISTICAL ANALYSIS (TEST NO. 1) - RESULTS OF  
BONFERRONI'S T-TEST ON MEAN NEONATE PRODUCTION  
AFTER 7 DAYS OF EXPOSURE

Conc (% by Vol)	No. of Reps	Mean No. Neonates Produced	T Statistic	Significance
UMD/WREC Control	9	28.8		
APG-EA Diluent Water	10	27.1	1.14	
10	10	27.3	1.01	
18	8	25.1	2.35	
32	10	21.9	4.68	*
56	10	16.3	8.49	*

\* Significantly different at  $\alpha = 0.05$  (Bonferroni's critical value = 2.40).

## APPENDIX 20

### CLADOCERAN ACUTE AND 7-DAY SURVIVAL AND REPRODUCTION TEST CONDUCTED ON BEACH POINT BUFFERED (pH $\approx$ 7) GROUNDWATER (WELL CC-33B) (TEST NO. 1)

Test Method:	EPA/600/4-89/001 (Weber et al., 1989)
Type of Test:	Static renewal (every 24 h)
Date:	April 7-14, 1993
Investigator:	S. D. Turley
Laboratory:	UMD/WREC
Groundwater:	
Source:	APG-EA Beach Point Well CC-33B
Chemical Characteristics:	See Appendix 48
Dilution Water:	
Source:	20% Perrier: 80% RO water
Chemical Characteristics:	See Table A20-1
Test Organism:	
Scientific Name:	<u>Ceriodaphnia dubia</u>
Age at Start of Test:	<4 h
Source:	UMD/WREC culture
Experimental Chambers:	
Material:	50 mL glass beaker
Test Solution Volume:	25 mL
No. Organisms/Replicate:	1
No. Organisms/Treatment:	10
Loading:	1 organism/beaker
Lighting:	Fluorescent; 60-85 foot candles
Aeration:	Prior to each renewal
pH Buffer:	10 N NaOH

Endpoints:

Mortality of adults; number of neonates produced in 3 broods

Water Quality:

Table A20-1

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Results:

Mortality:

48-h Exposure:

The data for the 48-h LC50 were obtained from the 7-d study. The buffered groundwater did not affect larval survival. The data are summarized in Table A20-2.

7-d Exposure:

Significant ( $\alpha = 0.05$ ) mortality occurred to the daphnids exposed to 100% and 56% buffered groundwater by volume; statistically significant mortality did not occur at 32% buffered groundwater by volume (see Tables A20-3, A20-4, and A20-5). The 7-d LC50 for adult mortality, which was determined by the moving average angle method, is as follows:

7-d LC50 = 43.3% buffered groundwater by volume (95% confidence limits = 1.00-56.42).

Neonate Production:

A significant ( $\alpha = 0.001$ ) reduction in neonate production relative to the controls occurred at 32% buffered groundwater by volume, which was the lowest concentration studied (see Tables A20-3 and A20-6). The NOEC and LOEC for exposure of the organism to buffered Beach Point groundwater could not be determined because a significant reduction in neonate production occurred at the lowest concentration studied. A comparison of the daphnid toxicity results between the raw and buffered Beach Point groundwater suggests that the buffered groundwater may have the same toxicity or may be more toxic than the raw groundwater. For example, the 7-d LC50 for mortality of the adults in the buffered groundwater was 43.3% groundwater by volume in contrast to 59.5% groundwater by volume in the raw groundwater. Neonate production was reduced in both sources down to 32% groundwater by volume. The reason(s) for this finding is not clear; however, it may be related to the fact that during the test, material precipitated out of solution which appeared to interfere with the daphnids as they foraged for food on the bottom of the exposure vessels.

TABLE A20-1. SUMMARY OF THE BEACH POINT BUFFERED GROUNDWATER  
BIOASSAY WATER QUALITY DATA FOR THE CLADOCERAN 7-  
DAY TEST (TEST NO. 1) - DISSOLVED OXYGEN (MG/L)

	<u>Test Concentrations (Percent Groundwater by Volume)</u>			
	0	32	56	100
<u>Day 0</u>				
0 H	8.8	7.8	8.1	8.2
<u>Day 1</u>				
0 H	8.2	7.9	7.9	5.6
24 H	8.1	8.1	8.1	8.0
<u>Day 2</u>				
0 H	8.2	8.1	8.0	6.6
24 H	7.6	7.6	7.6	7.6
<u>Day 3</u>				
0 H	8.4	8.1	8.1	6.8
24 H	7.6	7.5	7.5	7.5
<u>Day 4</u>				
0 H	8.4	8.2	8.0	6.2
24 H	8.5	8.4	8.2	8.3
<u>Day 5</u>				
0 H	8.3	8.1	8.1	5.1
24 H	8.5	8.3	8.1	8.2
<u>Day 6</u>				
0 H	8.5	8.0	8.1	5.9
24 H	8.4	8.2	8.2	8.3
<u>Day 7</u>				
24 H	8.1	8.0	8.0	8.0

TABLE A20-1. (CONTINUED) - pH (STANDARD UNITS)

		<u>Test Concentrations (Percent Groundwater by Volume)</u>			
		0	32	56	100
<u>Day 0</u>					
0 H		6.83	6.88	6.97	3.93
<u>Day 1</u>					
0 H		6.68	6.92	7.03	6.69
24 H		6.63	7.23	7.36	7.52
<u>Day 2</u>					
0 H		6.75	7.18	7.24	7.05
24 H		6.52	7.19	7.43	7.54
<u>Day 3</u>					
0 H		6.69	6.88	6.89	6.98
24 H		6.57	6.94	7.10	7.36
<u>Day 4</u>					
0 H		6.49	6.80	6.97	7.06
24 H		6.38	7.09	7.20	7.37
<u>Day 5</u>					
0 H		7.00	6.59	6.67	7.00
24 H		7.04	7.19	7.22	7.42
<u>Day 6</u>					
0 H		7.03	6.63	6.81	7.01
24 H		7.09	7.08	7.14	7.36
<u>Day 7</u>					
24 H		6.71	7.12	7.24	7.43

TABLE A20-1. (CONTINUED) - CONDUCTIVITY ( $\mu$ MHOS/CM)

	<u>Test Concentrations (Percent Groundwater by Volume)</u>	
	<u>0</u>	<u>100</u>
<u>Day 0</u>		
0 H	140	1700
<u>Day 1</u>		
0 H	170	1700
<u>Day 2</u>		
0 H	155	1700
<u>Day 3</u>		
0 H	155	1700
<u>Day 4</u>		
0 H	165	1750
<u>Day 5</u>		
0 H	160	1800
<u>Day 6</u>		
0 H	165	1750
<u>Day 7</u>		
24 H	158	1729



TABLE A20-1. (CONTINUED) - ALKALINITY (MG/L AS CaCO<sub>3</sub>)

<u>Test Concentrations (Percent Groundwater by Volume)</u>		
	<u>0</u>	<u>100</u>
<u>Day 0</u>		
0 H	50	80
<u>Day 1</u>		
0 H	50	80
<u>Day 2</u>		
0 H	50	85
<u>Day 3</u>		
0 H	50	85
<u>Day 4</u>		
0 H	50	100
<u>Day 5</u>		
0 H	50	85
<u>Day 6</u>		
0 H	50	85
<u>Day 7</u>		
24 H	50	85

TABLE A20-1. (CONTINUED) - HARDNESS (MG/L AS CaCO<sub>3</sub>)

	<u>Test Concentrations (Percent Groundwater by Volume)</u>	
	0	100
<u>Day 0</u>		
0 H	48	280
<u>Day 1</u>		
0 H	46	170
<u>Day 2</u>		
0 H	56	136
<u>Day 3</u>		
0 H	50	148
<u>Day 4</u>		
0 H	52	138
<u>Day 5</u>		
0 H	54	160
<u>Day 6</u>		
0 H	54	148
<u>Day 7</u>		
24 H	51	168

TABLE A20-2 CLADOCERAN BEACH POINT BUFFERED GROUNDWATER TOXICITY  
TEST DATA (TEST NO. 1) - SURVIVAL AFTER 48 HOURS OF  
EXPOSURE

Concentration (% Groundwater by Volume)	Number Tested	No. Alive at 48 Hours	Percent Alive
UMD/WREC Control	10	10	100
10	10	10	100
18	10	10	100
32	10	10	100
56	10	10	100
100	10	9	90

TABLE A20-3. CLADOCERAN BEACH POINT BUFFERED GROUNDWATER  
TOXICITY DATA (TEST NO.1) - SURVIVAL OF ADULTS,  
NUMBER OF YOUNG PRODUCED PER BROOD, TOTAL NUMBER OF  
YOUNG, AND MEAN NUMBER OF YOUNG PRODUCED PER BROOD  
AFTER 7 DAYS OF EXPOSURE

Conc (% by Vol)	Rep	Brood No. 1	Brood No. 2	Brood No. 3	Total Young	Mean Young Per Brood
UMD/WREC Control	1	6	13	13	32	10.7
	2	4	12	12	28	9.3
	3	7	11	11	29	9.7
	4	4	10	11	25	8.3
	5	3	14	13	30	10.0
	6	5	7	13	25	8.3
	7	7	11	11	29	9.7
	8	a				
	9	4	14	15	33	11.0
	10	5	12	11	28	9.3
32	1	7	3	DEAD	10	5.0
	2	5	2	10	17	5.7
	3	7	10	6	23	7.7
	4	a				
	5	6	7	DEAD	13	6.5
	6	5	5	4	14	4.7
	7	6	9	5	20	6.7
	8	7	DEAD		7	7.0
	9	7	12	10	29	9.7
	10	a				
56	1	4	7	DEAD	11	5.5
	2	4	3	DEAD	7	3.5
	3	3	0	0	3	3.0
	4	6	DEAD		6	6.0
	5	6	6	0	12	6.0
	6	5	5	DEAD	10	5.0
	7	4	DEAD		4	4.0
	8	3	0	0	3	3.0
	9	5	0	0	5	5.0
	10	4	DEAD		4	4.0

TABLE A20-3. (CONTINUED)

Conc (% by Vol)	Rep	Brood No. 1	Brood No. 2	Brood No. 3	Total Young	Mean Young Per Brood
100	1	DEAD				
	2	DEAD				
	3	DEAD				
	4	DEAD				
	5	DEAD				
	6	2	DEAD		2	2.0
	7	DEAD				
	8	DEAD				
	9	DEAD				
	10	DEAD				

<sup>a</sup> Male adult, which was included in survival analysis, was not included in the neonate production analysis.

TABLE A20-4. CLADOCERAN BEACH POINT BUFFERED GROUNDWATER  
TOXICITY TEST STATISTICAL ANALYSIS (TEST NO. 1) -  
ADULT SURVIVAL AFTER 7 DAYS OF EXPOSURE<sup>a</sup>

---

Data Transformation:

None

Fisher's Exact Test:

Calculated test statistic:	See Table A14-4
Alpha value:	0.05
Critical value:	6
Conclusion:	Reject the null hypothesis that all groups are equal.

---

<sup>a</sup> The 100% buffered Beach Point groundwater treatment was not included in the statistical analyses because all organisms died during the test.

TABLE A20-5. CLADOCERAN BEACH POINT BUFFERED GROUNDWATER  
TOXICITY TEST STATISTICAL ANALYSIS (TEST NO. 1) -  
RESULTS OF FISHER'S EXACT TEST ON ADULT SURVIVAL  
AFTER 7 DAYS OF EXPOSURE

Conc (% by Vol)	Number Alive	Number Dead	b Value	Significance
UMD/WREC Control	10	0		
32	7	3	7	
56	4	6	4	*

\* Significantly different at  $\alpha = 0.05$  (Fisher's critical value = 6).

TABLE A20-6. CLADOCERAN BEACH POINT BUFFERED GROUNDWATER  
TOXICITY TEST STATISTICAL ANALYSIS (TEST NO. 1) -  
NEONATE PRODUCTION AFTER 7 DAYS OF EXPOSURE<sup>a</sup>

---

Data Transformation:

None

Chi-Square Test for Normality:

Calculated test statistic:	1.81
Alpha value:	0.01
Critical value:	13.28
Conclusion:	Fail to reject the null hypothesis that the data are normally distributed

Bartlett's Test for Homogeneity of Variances:

Calculated test statistic:	8.24
Alpha value:	0.01
Critical value:	9.21
Conclusion:	Fail to reject the null hypothesis that the variances are homogenous

Student's T-test:

Calculated test statistic:	4.72
Alpha value:	0.001
Critical value:	4.07
Conclusion:	Reject the null hypothesis that all groups are equal

---

<sup>a</sup> The 56% buffered Beach Point groundwater treatment was not included in the statistical analyses because all concentrations above the NOEC for survival are excluded from the hypothesis test for reproductive effects.



APPENDIX 21

CLADOCERAN ACUTE AND 7-DAY SURVIVAL AND REPRODUCTION  
TEST CONDUCTED ON BEACH POINT RAW (pH  $\approx$ 4)  
GROUNDWATER (WELL CC-33B)  
(TEST NO. 2)

Test Method: EPA/600/4-89/001  
(Weber et al., 1989)

Type of Test: Static renewal (every 24 h)

Date: June 1-8, 1993

Investigator: S.D. Turley

Laboratory: UMD/WREC

Groundwater:

Source: APG-EA Beach Point Well CC-33B  
Chemical Characteristics: See Appendix 48

Dilution Water:

Source: 20% Perrier: 80% RO water  
Chemical Characteristics: See Table A21-1

Test Organism:

Scientific Name: Ceriodaphnia dubia  
Age at Start of Test: <4 h  
Source: UMD/WREC culture

Experimental Chambers:

Material: 50 mL glass beaker  
Test Solution Volume: 25 mL

No. Organisms/Replicate: 1

No. Organisms/Treatment: 10

Loading: 1 organism/beaker

Lighting: Fluorescent; 60-85 foot  
candles

Aeration: Prior to each renewal

Endpoints:

Mortality of adults; number of  
neonates produced in 3 broods

Water Quality:

Table A21-1

---

Results:

Mortality:

48-h Exposure:

The data for the 48-h LC50 were obtained from the 7-d study. All organisms exposed to 100% raw groundwater died during the 48-h exposure (Table A21-2). The organisms in all other treatments lived. The 48-h LC50, which was determined by the moving average angle method, is as follows:

48-h LC50 = 64.7% raw groundwater by volume (95% confidence  
limits = 57.17-75.48).

7-d Exposure:

Significant ( $\alpha = 0.05$ ) mortality occurred in the adults exposed to 100% raw groundwater (see Table A21-3). The 7-d LC50, which was determined by the moving average angle method, is as follows:

7-d LC50 = 64.7% raw groundwater by volume (95% confidence  
limits = 57.17-75.48).

Neonate Production:

Raw groundwater significantly ( $\alpha = 0.05$ ) reduced neonate production relative to the controls down to 18% raw groundwater by volume (see Tables A21-3, A21-4, and A21-5). The NOEC and LOEC for the daphnids, based on reduced neonate production, are as follows:

NOEC = 10% raw groundwater by volume.  
LOEC = 18% raw groundwater by volume.

TABLE A21-1. SUMMARY OF THE BEACH POINT RAW GROUNDWATER BIOASSAY  
WATER QUALITY DATA FOR THE CLADOCERAN 7-DAY TEST  
(TEST NO. 2) - DISSOLVED OXYGEN (MG/L)

		<u>Test Concentrations (Percent Groundwater by Volume)</u>					
		0	10	18	32	56	100
<u>Day 0</u>							
0 H		8.3	8.3	8.2	8.0	7.9	6.8
<u>Day 1</u>							
0 H		8.3	8.3	8.2	7.9	7.6	6.6
24 H		8.2	8.0	8.0	8.0	8.0	8.1
<u>Day 2</u>							
0 H		8.0	8.0	7.9	7.4	7.1	7.2
24 H		8.1	8.0	7.9	7.9	7.9	7.7
<u>Day 3</u>							
0 H		8.3	8.0	8.0	7.9	7.9	7.1
24 H		7.8	7.4	7.3	7.2	7.2	
<u>Day 4</u>							
0 H		8.3	8.2	8.1	8.1	7.8	
24 H		8.3	8.1	8.1	7.8	7.8	
<u>Day 5</u>							
0 H		8.2	8.1	8.0	7.8	7.6	
24 H		8.3	8.2	8.3	8.0	8.0	
<u>Day 6</u>							
0 H		8.5	8.4	8.2	8.2	8.1	
24 H		8.2	8.1	8.1	8.2	8.1	
<u>Day 7</u>							
24 H		8.1	8.0	8.0	8.0	8.0	

TABLE A21-1. (CONTINUED) - pH (STANDARD UNITS)

	Test Concentrations (Percent Groundwater by Volume)					
	0	10	18	32	56	100
<u>Day 0</u>						
0 H	7.49	7.33	6.96	6.70	6.27	3.97
<u>Day 1</u>						
0 H	6.93	6.96	6.92	6.62	6.25	4.06
24 H	6.80	7.06	7.14	7.23	7.28	5.58
<u>Day 2</u>						
0 H	6.36	6.32	6.23	6.14	5.70	3.95
24 H	7.39	7.43	7.51	7.58	7.59	5.49
<u>Day 3</u>						
0 H	6.35	6.31	6.31	6.19	5.85	3.96
24 H	6.35	6.63	6.72	6.79	6.84	
<u>Day 4</u>						
0 H	6.29	6.24	6.25	6.20	6.13	
24 H	6.23	6.15	6.29	6.39	6.44	
<u>Day 5</u>						
0 H	6.54	6.55	6.58	6.57	5.94	
24 H	7.13	7.14	7.24	7.30	7.34	
<u>Day 6</u>						
0 H	6.43	6.62	6.67	6.67	6.19	
24 H	6.97	7.12	7.24	7.35	7.41	
<u>Day 7</u>						
24 H	6.90	7.06	7.11	7.24	7.33	

TABLE A21-1. (CONTINUED) - CONDUCTIVITY ( $\mu$ MHOS/CM)

<u>Test Concentrations (Percent Groundwater by Volume)</u>		
	<u>0</u>	<u>100</u>
<u>Day 0</u>		
0 H	180	1350
<u>Day 1</u>		
0 H	160	1600
<u>Day 2</u>		
0 H	80	
<u>Day 3</u>		
0 H	90	
<u>Day 4</u>		
0 H	90	
<u>Day 5</u>		
0 H	140	
<u>Day 6</u>		
0 H	140	
<u>Day 7</u>		
24 H	130	

TABLE A21-1. (CONTINUED) - ALKALINITY (MG/L AS CaCO<sub>3</sub>)

	<u>Test Concentrations (Percent Groundwater by Volume)</u>	
	0	100
<u>Day 0</u>		
0 H	50	a
<u>Day 1</u>		
0 H	65	a
<u>Day 2</u>		
0 H	25	
<u>Day 3</u>		
0 H	25	
<u>Day 4</u>		
0 H	25	
<u>Day 5</u>		
0 H	55	
<u>Day 6</u>		
0 H	60	
<u>Day 7</u>		
24 H	50	

<sup>a</sup> Could not obtain measurement.

TABLE A21-1. (CONTINUED) - HARDNESS (MG/L AS  $\text{CaCO}_3$ )

	<u>Test Concentrations (Percent Groundwater by Volume)</u>	
	0	100
<u>Day 0</u>		
0 H	50	a
<u>Day 1</u>		
0 H	60	a
<u>Day 2</u>		
0 H	36	
<u>Day 3</u>		
0 H	24	
<u>Day 4</u>		
0 H	24	
<u>Day 5</u>		
0 H	50	
<u>Day 6</u>		
0 H	54	
<u>Day 7</u>		
24 H	50	

<sup>a</sup> Could not obtain measurement.

TABLE A21-2. CLADOCERAN BEACH POINT RAW GROUNDWATER TOXICITY  
TEST DATA (TEST NO. 1) - SURVIVAL AFTER 48 HOURS OF  
EXPOSURE

Concentration (% Groundwater by Volume)	Number Tested	No. Alive at 48 Hours	Percent Alive
UMD/WREC Control	10	10	100
10	10	10	100
18	10	10	100
32	10	10	100
56	10	10	100
100	10	0	0



TABLE A21-3. CLADOCERAN BEACH POINT RAW GROUNDWATER TOXICITY DATA (TEST NO. 2) - SURVIVAL OF ADULTS, NUMBER OF YOUNG PRODUCED PER BROOD, TOTAL NUMBER OF YOUNG, AND MEAN NUMBER OF YOUNG PER BROOD AFTER 7 DAYS OF EXPOSURE

Conc (% by Vol)	Rep	Brood No. 1	Brood No. 2	Brood No. 3	Total Young	Mean Young Per Brood
UMD/WREC Control	1	4	10	22	36	12.0
	2	4	8	15	27	9.0
	3	4	8	15	27	9.0
	4	3	7	10	20	6.7
	5	6	7	14	27	9.0
	6	4	6	12	22	7.3
	7	4	7	16	27	9.0
	8	5	8	10	23	7.7
	9	6	8	12	26	8.7
	10	11	12	13	36	12.0
APG-EA Diluent Water	1	4	9	23	36	12.0
	2	3	10	19	32	10.7
	3	5	9	17	31	10.3
	4	5	7	19	31	10.3
	5	4	13	12	29	9.9
	6	6	9	13	28	9.3
	7	5	12	15	32	10.7
	8	5	8	8	21	7.0
	9	4	8	16	28	9.3
	10	4	9	16	29	9.7
10	1	4	5	12	20	6.7
	2	5	8	13	26	8.7
	3	5	6	14	25	8.3
	4	5	6	15	26	8.7
	5	4	9	16	29	9.7
	6	4	0	13	17	8.5
	7	4	3	14	21	7.0
	8	5	7	12	24	8.0
	9	4	8	18	30	10.0
	10	5	9	13	27	9.0

TABLE A21-3. (CONTINUED)

Conc (% by Vol)	Rep	Brood No. 1	Brood No. 2	Brood No. 3	Total Young	Mean Young Per Brood
18	1	2	7	13	22	7.3
	2	4	7	12	23	7.7
	3	4	6	10	20	6.7
	4	4	7	9	20	6.7
	5	3	6	9	18	6.0
	6	5	10	12	27	9.0
	7	3	6	15	24	8.0
	8	4	9	10	23	7.7
	9	4	1	12	17	5.7
	10	4	9	13	26	8.7
32	1	2	6	13	21	7.0
	2	4	8	9	21	7.0
	3	4	6	8	18	6.0
	4	3	4	9	16	5.3
	5	4	7	8	19	6.3
	6	3	5	6	14	4.7
	7	2	5	8	15	5.0
	8	4	7	8	19	6.3
	9	3	5	11	19	6.3
	10	3	7	5	15	5.0
56	1	1	1	2	4	1.3
	2	2	1	0	3	1.5
	3	1	1	0	2	1.0
	4	1	0	0	1	1.0
	5	2	1	4	7	2.3
	6	2	0	0	2	2.0
	7	2	0	3	5	2.5
	8	3	1	0	4	2.0
	9	3	0	0	3	3.0
	10	2	2	1	5	1.7

TABLE A21-3. (CONTINUED)

Conc (% by Vol)	Rep	Brood No. 1	Brood No. 2	Brood No. 3	Total Young	Mean Young Per Brood
100	1	DEAD				
	2	DEAD				
	3	DEAD				
	4	DEAD				
	5	DEAD				
	6	DEAD				
	7	DEAD				
	8	DEAD				
	9	DEAD				
	10	DEAD				

TABLE A21-4. CLADOCERAN BEACH POINT RAW GROUNDWATER TOXICITY  
TEST STATISTICAL ANALYSIS (TEST NO. 2) - NEONATE  
PRODUCTION AFTER 7 DAYS OF EXPOSURE<sup>a</sup>

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Data Transformation:

None

Chi-square Test for Normality:

Calculated test statistic:	0.70
Alpha value:	0.01
Critical value:	13.28
Conclusion	Fail to reject the null hypothesis that the data are normally distributed

Bartlett's Test for Homogeneity of Variances:

Calculated test statistic:	11.25
Alpha value:	0.01
Critical value:	15.09
Conclusion:	Fail to reject the null hypothesis that the variances are homogenous

ANOVA:

Calculated test statistic:	65.48
Alpha value:	0.05
Critical value:	2.45
Conclusion:	Reject the null hypothesis that all groups are equal

Dunnett's T-test:

Calculated test statistics:	See Table A21-5
Alpha value:	0.05
Critical value:	2.31
Conclusion:	Reject the null hypothesis that all groups are equal

---

<sup>a</sup> The 100% raw Beach Point groundwater treatment was not included in the statistical analyses because all concentrations above the NOEC for survival are excluded from the hypothesis test for reproductive effects.

TABLE A21-5. CLADOCERAN BEACH POINT RAW GROUNDWATER TOXICITY  
TEST STATISTICAL ANALYSIS (TEST NO. 2) - RESULTS OF  
DUNNETT'S TEST ON MEAN NEONATE PRODUCTION AFTER 7  
DAYS OF EXPOSURE

Conc (% by Vol)	No. of Reps	Mean No. Neonates Produced	T Statistic	Significance
UMD/WREC Control	10	27.1		
APG-EA Diluent Water	10	29.5	-1.47	
10	10	24.6	1.53	
18	10	22.0	3.12	*
32	10	17.7	5.76	*
56	10	3.6	14.39	*

\* Significantly different at alpha = 0.05 (Dunnett's critical  
value = 2.31).

## APPENDIX 22

### CLADOCERAN ACUTE AND 7-DAY SURVIVAL AND REPRODUCTION TEST CONDUCTED ON BEACH POINT BUFFERED (pH $\approx$ 7) GROUNDWATER (WELL CC-33B) (TEST NO. 2)

Test Method:	EPA/600/4-89/001 (Weber et al., 1989)
Type of Test:	Static renewal (every 24 h)
Date:	June 1-8, 1993
Investigator:	S. D. Turley
Laboratory:	UMD/WREC
Groundwater:	
Source:	APG-EA Beach Point Well CC-33B
Chemical Characteristics:	See Appendix 48
Dilution Water:	
Source:	20% Perrier: 80% RO water
Chemical Characteristics:	See Table A22-1
Test Organism:	
Scientific Name:	<u>Ceriodaphnia dubia</u>
Age at Start of Test:	<4 h
Source:	UMD/WREC culture
Experimental Chambers:	
Material:	50 mL glass beaker
Test Solution Volume:	25 mL
No. Organisms/Replicate:	1
No. Organisms/Treatment:	10
Loading:	1 organism/beaker
Lighting:	Fluorescent; 60-85 foot candles
Aeration:	Prior to each renewal
pH Buffer:	10 N NaOH

Endpoints:

Mortality of adults; number of neonates produced in 3 broods

Water Quality:

Table A22-1

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Results:

Mortality:

48-h Exposure:

The data for the 48-h LC50 were obtained from the 7-d study. The buffered groundwater did not affect survival. The data are summarized in Table A22-2.

7-d Exposure:

Significant ( $\alpha = 0.05$ ) mortality occurred to the daphnids exposed to 100% buffered groundwater by volume; statistically significant mortality did not occur at 56% buffered groundwater by volume (see Tables A22-3, A22-4, and A22-5). The 7-d LC50 for adult mortality, which was determined by the moving average angle method, is as follows:

7-d LC50 = 71.8% buffered groundwater by volume (95% confidence limits = 53.77-155.81)

Neonate Production:

Significant ( $\alpha = 0.05$ ) reductions in neonate production relative to the controls occurred at all concentrations down to 18% buffered groundwater by volume, which was the lowest concentration studied (see Tables A22-3, A22-6, and A22-7). The NOEC and LOEC for exposure of the organism to buffered Beach Point groundwater could not be determined because a significant reduction in neonate production occurred at the lowest concentration studied.

TABLE A22-1. SUMMARY OF THE BEACH POINT BUFFERED GROUNDWATER  
BIOASSAY WATER QUALITY DATA FOR THE CLADOCERAN 7-  
DAY TEST (TEST NO. 2) - DISSOLVED OXYGEN (MG/L)

	<u>Test Concentrations (Percent Groundwater by Volume)</u>				
	0	18	32	56	100
<u>Day 0</u>					
0 H	8.3	7.7	7.5	7.5	6.7
<u>Day 1</u>					
0 H	8.3	8.2	8.0	7.6	6.5
24 H	8.1	8.0	8.1	8.1	8.2
<u>Day 2</u>					
0 H	8.0	8.4	8.4	8.2	7.1
24 H	8.1	7.9	8.0	8.0	8.1
<u>Day 3</u>					
0 H	8.3	8.1	7.8	7.5	6.2
24 H	7.8	8.4	8.4	8.4	8.4
<u>Day 4</u>					
0 H	8.3	7.8	7.6	7.5	6.5
24 H	8.3	8.2	8.4	8.3	8.3
<u>Day 5</u>					
0 H	8.2	8.2	8.2	8.2	8.0
24 H	8.3	8.3	8.2	8.2	8.1
<u>Day 6</u>					
0 H	8.5	8.3	8.1	8.4	8.0
24 H	8.2	8.2	8.1	8.2	8.1
<u>Day 7</u>					
24 H	8.1	8.1	8.0	8.0	7.9



TABLE A22-1. (CONTINUED) - pH (STANDARD UNITS)

	<u>Test Concentrations (Percent Groundwater by Volume)</u>				
	0	18	32	56	100
<u>Day 0</u>					
0 H	7.49	6.88	6.85	6.87	6.95
<u>Day 1</u>					
0 H	6.93	6.60	6.76	6.89	6.96
24 H	6.80	6.63	6.84	7.06	7.24
<u>Day 2</u>					
0 H	6.36	6.50	6.60	6.88	7.25
24 H	7.39	7.60	7.72	7.87	8.00
<u>Day 3</u>					
0 H	6.35	6.82	6.94	7.12	7.60
24 H	6.35	7.04	7.13	7.29	7.38
<u>Day 4</u>					
0 H	6.29	6.52	6.91	6.92	7.32
24 H	6.23	6.57	6.92	7.16	7.66
<u>Day 5</u>					
0 H	6.54	7.16	7.20	7.29	7.18
24 H	7.13	7.36	7.43	7.54	7.69
<u>Day 6</u>					
0 H	6.43	6.79	6.91	7.13	7.57
24 H	6.97	7.56	7.55	7.71	7.93
<u>Day 7</u>					
24 H	6.90	7.40	7.46	7.60	7.80

TABLE A22-1. (CONTINUED) - CONDUCTIVITY ( $\mu$ MHOS/CM)

	<u>Test Concentrations (Percent Groundwater by Volume)</u>	
	0	100
<u>Day 0</u>		
0 H	180	1180
<u>Day 1</u>		
0 H	160	1400
<u>Day 2</u>		
0 H	80	1600
<u>Day 3</u>		
0 H	90	1500
<u>Day 4</u>		
0 H	90	1700
<u>Day 5</u>		
0 H	140	1350
<u>Day 6</u>		
0 H	140	1700
<u>Day 7</u>		
24 H	160	1700

TABLE A22-1. (CONTINUED) - ALKALINITY (MG/L AS CaCO<sub>3</sub>)

	<u>Test Concentrations (Percent Groundwater by Volume)</u>	
	0	100
<u>Day 0</u>		
0 H	50	100
<u>Day 1</u>		
0 H	65	100
<u>Day 2</u>		
0 H	25	120
<u>Day 3</u>		
0 H	25	110
<u>Day 4</u>		
0 H	25	125
<u>Day 5</u>		
0 H	55	125
<u>Day 6</u>		
0 H	60	125
<u>Day 7</u>		
24 H	50	105

TABLE A22-1. (CONTINUED) - HARDNESS (MG/L AS CaCO<sub>3</sub>)

	<u>Test Concentrations (Percent Groundwater by Volume)</u>	
	0	100
<u>Day 0</u>		
0 H	50	190
<u>Day 1</u>		
0 H	60	170
<u>Day 2</u>		
0 H	36	128
<u>Day 3</u>		
0 H	24	148
<u>Day 4</u>		
0 H	24	134
<u>Day 5</u>		
0 H	50	154
<u>Day 6</u>		
0 H	54	170
<u>Day 7</u>		
24 H	50	168

TABLE A22-2. CLADOCERAN BEACH POINT BUFFERED GROUNDWATER  
TOXICITY TEST DATA (TEST NO. 2) - SURVIVAL AFTER 48  
HOURS OF EXPOSURE

Concentration (% Groundwater by Volume)	Number Tested	No. Alive at 48 Hours	Percent Alive
UMD/WREC Control	10	10	100
10	10	10	100
18	10	10	100
32	10	10	100
56	10	10	100
100	10	10	100

TABLE A22-3. CLADOCERAN BEACH POINT BUFFERED GROUNDWATER  
TOXICITY DATA (TEST NO.2) - SURVIVAL OF ADULTS,  
NUMBER OF YOUNG PRODUCED PER BROOD, TOTAL NUMBER OF  
YOUNG, AND MEAN NUMBER OF YOUNG PRODUCED PER BROOD  
AFTER 7 DAYS OF EXPOSURE

Conc (% by Vol)	Rep	Brood No. 1	Brood No. 2	Brood No. 3	Total Young	Mean Young Per Brood
UMD/WREC Control	1	4	10	22	36	12.0
	2	4	8	15	27	9.0
	3	4	8	15	27	9.0
	4	3	7	10	20	6.7
	5	6	7	14	27	9.0
	6	4	6	12	22	7.3
	7	4	7	16	27	9.0
	8	5	8	10	23	7.7
	9	6	8	12	26	8.7
	10	11	12	13	36	12.0
18	1	3	0	5	8	4.0
	2	5	0	0	5	5.0
	3	5	0	4	9	4.5
	4	4	0	8	12	6.0
	5	4	0	0	4	4.0
	6	5	0	6	11	5.5
	7	4	0	0	4	4.0
	8	1	5	0	6	3.0
	9	2	1	5	8	2.7
	10	4	0	4	8	4.0
32	1	4	1	0	5	2.5
	2	4	2	DEAD	6	3.0
	3	4	0	0	4	4.0
	4	4	0	4	8	4.0
	5	4	0	3	7	3.5
	6	4	0	3	7	3.5
	7	3	0	4	7	3.5
	8	4	0	3	7	3.5
	9	5	0	4	9	4.5
	10	2	1	3	6	2.0

TABLE A22-3. (CONTINUED)

Conc (% by Vol)	Rep	Brood No. 1	Brood No. 2	Brood No. 3	Total Young	Mean Young Per Brood
56	1	4	4	0	8	4.0
	2	2	4	0	6	3.0
	3	0	1	0	1	1.0
	4	4	6	0	10	5.0
	5	4	1	0	5	2.5
	6	2	5	0	7	3.5
	7	4	DEAD		4	4.0
	8	2	4	0	6	3.0
	9	4	6	DEAD	10	5.0
	10	3	3	DEAD	6	3.0
100	1	0	3	DEAD	3	3.0
	2	0	3	0	3	3.0
	3	0	3	DEAD	3	3.0
	4	1	0	DEAD	1	1.0
	5	0	4	0	4	4.0
	6	0	4	DEAD	4	4.0
	7	0	3	DEAD	3	3.0
	8	4	0	DEAD	4	4.0
	9	0	4	DEAD	4	4.0
	10	0	4	DEAD	4	4.0

TABLE A22-4. CLADOCERAN BEACH POINT BUFFERED GROUNDWATER  
TOXICITY TEST STATISTICAL ANALYSIS (TEST NO. 2) -  
ADULT SURVIVAL AFTER 7 DAYS OF EXPOSURE

---

Data Transformation:

None

Fisher's Exact Test:

Calculated test statistic:	See Table A22-5
Alpha value:	0.05
Critical value:	6
Conclusion:	Reject the null hypothesis that all groups are equal.

---



TABLE A22-5. CLADOCERAN BEACH POINT BUFFERED GROUNDWATER  
TOXICITY TEST STATISTICAL ANALYSIS (TEST NO. 2) -  
RESULTS OF FISHER'S EXACT TEST ON ADULT SURVIVAL  
AFTER 7 DAYS OF EXPOSURE

Conc (% by Vol)	Number Alive	Number Dead	b Value	Significance
UMD/WREC Control	10	0		
18	10	0	10	
32	9	1	9	
56	7	3	7	
100	2	8	2	*

\* Significantly different at  $\alpha = 0.05$  (Fisher's critical value = 6).

TABLE A22-6. CLADOCERAN BEACH POINT BUFFERED GROUNDWATER  
TOXICITY TEST STATISTICAL ANALYSIS (TEST NO. 2) -  
NEONATE PRODUCTION AFTER 7 DAYS OF EXPOSURE<sup>a</sup>

---

Data Transformation:

None

Chi-Square Test for Normality:

Calculated test statistic:	3.18
Alpha value:	0.01
Critical value:	13.28
Conclusion:	Fail to reject the null hypothesis that the data are normally distributed

Bartlett's Test for Homogeneity of Variances:

Calculated test statistic:	13.90
Alpha value:	0.01
Critical value:	11.34
Conclusion:	Reject the null hypothesis that the variances are homogenous

Steel's Many-One Rank Test:

Calculated test statistics:	See Table A22-7
Alpha value:	0.05
Critical value:	77.0
Conclusion:	Reject the null hypothesis that all groups are equal

---

<sup>a</sup> The 100% buffered Beach Point groundwater treatment was not included in the statistical analyses because all concentrations above the NOEC for survival are excluded from the hypothesis test for reproductive effects.

TABLE A22-7. CLADOCERAN BEACH POINT BUFFERED GROUNDWATER  
TOXICITY STATISTICAL ANALYSIS (TEST NO. 2) -  
RESULTS OF STEEL'S MANY-ONE RANK TEST ON MEAN  
NEONATE PRODUCTION AFTER 7 DAYS OF EXPOSURE

Conc (% by Vol)	No. of Reps	Mean No. Neonates Produced	Rank Sum	Significance
UMD/WREC Control	10	27.1		
18	10	7.5	55.0	*
32	10	6.6	55.0	*
56	10	6.3	55.0	*

\* Significantly different at  $\alpha = 0.05$  (Steel's critical  
value = 77.0).

## APPENDIX 23

### CLADOCERAN ACUTE AND 7-DAY SURVIVAL AND REPRODUCTION TEST CONDUCTED ON BEACH POINT RAW (pH $\approx$ 4) GROUNDWATER (WELL CC-33B) (TEST NO. 3)

Test Method:	EPA/600/4-89/001 (Weber et al., 1989)
Type of Test:	Static renewal (every 24 h)
Date:	August 24-31, 1993
Investigator:	S.D. Turley
Laboratory:	UMD/WREC
Groundwater:	
Source:	APG-EA Beach Point Well CC-33B
Chemical Characteristics:	See Appendix 48
Dilution Water:	
Source:	20% Perrier: 80% RO water
Chemical Characteristics:	See Table A23-1
Test Organism:	
Scientific Name:	<u>Ceriodaphnia dubia</u>
Age at Start of Test:	<4 h
Source:	UMD/WREC culture
Experimental Chambers:	
Material:	50 mL glass beaker
Test Solution Volume:	25 mL
No. Organisms/Replicate:	1
No. Organisms/Treatment:	10
Loading:	1 organism/beaker
Lighting:	Fluorescent; 60-85 foot candles
Aeration:	Prior to each renewal

Endpoints:

Mortality of adults; number of neonates produced in 3 broods

Water Quality:

Table A23-1

---

Results:

Mortality:

48-h Exposure:

The data for the 48-h LC50 were obtained from the 7-d study. All organisms exposed to 100% raw groundwater died during the 48-h exposure (Table A23-2). The organisms in all other treatments lived. The 48-h LC50, which was determined by the moving average angle method, is as follows:

48-h LC50 = 64.7% raw groundwater by volume (95% confidence limits = 57.17-75.48).

7-d Exposure:

All organisms exposed to 100% raw groundwater died during the 7-d exposure (Table A23-3). Survival was not affected by exposure to concentrations up to 56% raw groundwater by volume. The 7-d LC50, which was determined by the moving average angle method, is as follows:

7-d LC50 = 64.7% raw groundwater by volume (95% confidence limits = 57.17-75.48).

Neonate Production:

Raw groundwater significantly ( $\alpha = 0.05$ ) reduced neonate production relative to the controls down to 18% raw groundwater by volume (see Tables A23-3, A23-4, and A23-5). The NOEC and LOEC for the daphnids, based on reduced neonate production, are as follows:

NOEC = 10% raw groundwater by volume.

LOEC = 18% raw groundwater by volume.

TABLE A23-1. SUMMARY OF THE BEACH POINT RAW GROUNDWATER BIOASSAY  
WATER QUALITY DATA FOR THE CLADOCERAN 7-DAY TEST  
(TEST NO. 3) - DISSOLVED OXYGEN (MG/L)

	<u>Test Concentrations (Percent Groundwater by Volume)</u>					
	0	10	18	32	56	100
<u>Day 0</u>						
0 H	8.2	8.0	7.8	7.5	7.1	5.4
<u>Day 1</u>						
0 H	8.1	8.1	8.0	7.7	7.3	
24 H	8.0	7.8	7.7	7.7	7.8	
<u>Day 2</u>						
0 H	8.1	8.1	8.1	8.0	7.9	
24 H	7.5	8.0	8.3	8.1	8.3	
<u>Day 3</u>						
0 H	8.2	8.0	7.8	7.9	7.5	
24 H	7.1	7.1	7.0	7.8	7.7	
<u>Day 4</u>						
0 H	8.1	8.0	7.9	7.8	7.8	
24 H	7.7	7.4	7.8	7.7	7.6	
<u>Day 5</u>						
0 H	8.2	7.9	7.9	7.9	7.5	
24 H	7.3	7.1	7.5	7.5	7.5	
<u>Day 6</u>						
0 H	8.4	7.9	7.8	7.7	7.2	
24 H	7.6	7.8	7.9	8.0	8.0	
<u>Day 7</u>						
24 H	8.2	8.0	8.2	8.1	8.2	

TABLE A23-1. (CONTINUED) - pH (STANDARD UNITS)

	<u>Test Concentrations (Percent Groundwater by Volume)</u>					
	0	10	18	32	56	100
<u>Day 0</u>						
0 H	7.64	7.20	6.88	6.47	5.89	3.92
<u>Day 1</u>						
0 H	7.69	7.30	6.91	6.53	5.99	
24 H	7.97	8.05	8.17	8.18	8.08	
<u>Day 2</u>						
0 H	7.83	6.91	6.78	6.53	6.65	
24 H	7.46	7.84	7.99	7.94	7.81	
<u>Day 3</u>						
0 H	7.75	7.34	7.11	6.79	6.33	
24 H	8.09	7.94	7.95	7.92	7.83	
<u>Day 4</u>						
0 H	7.84	7.86	7.51	6.82	6.20	
24 H	7.50	7.62	7.67	7.64	7.52	
<u>Day 5</u>						
0 H	7.57	7.50	7.12	6.70	5.87	
24 H	7.54	7.68	7.69	7.66	7.53	
<u>Day 6</u>						
0 H	7.31	7.10	6.82	6.52	5.84	
24 H	7.94	7.85	7.84	7.83	7.61	
<u>Day 7</u>						
24 H	8.03	8.05	8.04	7.96	7.86	

TABLE A23-1. (CONTINUED) - CONDUCTIVITY ( $\mu$ MHOS/CM)

	<u>Test Concentrations (Percent Groundwater by Volume)</u>	
	0	100
<u>Day 0</u>		
0 H	150	1750
<u>Day 1</u>		
0 H	140	
<u>Day 2</u>		
0 H	160	
<u>Day 3</u>		
0 H	150	
<u>Day 4</u>		
0 H	150	
<u>Day 5</u>		
0 H	150	
<u>Day 6</u>		
0 H	150	
<u>Day 7</u>		
24 H	150	



TABLE A23-1. (CONTINUED) - ALKALINITY (MG/L AS CaCO<sub>3</sub>)

<u>Test Concentrations (Percent Groundwater by Volume)</u>		
	<u>0</u>	<u>100</u>
<u>Day 0</u>		
0 H	40	<sup>a</sup>
<u>Day 1</u>		
0 H	40	<sup>a</sup>
<u>Day 2</u>		
0 H	60	
<u>Day 3</u>		
0 H	45	
<u>Day 4</u>		
0 H	55	
<u>Day 5</u>		
0 H	50	
<u>Day 6</u>		
0 H	60	
<u>Day 7</u>		
24 H	55	

<sup>a</sup> Could not obtain measurement.

TABLE A23-1. (CONTINUED) - HARDNESS (MG/L AS  $\text{CaCO}_3$ )

<u>Test Concentrations (Percent Groundwater by Volume)</u>		
	<u>0</u>	<u>100</u>
<u>Day 0</u>		
0 H	54	a
<u>Day 1</u>		
0 H	50	a
<u>Day 2</u>		
0 H	62	
<u>Day 3</u>		
0 H	50	
<u>Day 4</u>		
0 H	56	
<u>Day 5</u>		
0 H	52	
<u>Day 6</u>		
0 H	50	
<u>Day 7</u>		
24 H	62	

<sup>a</sup> Could not obtain measurement.

TABLE A23-2. CLADOCERAN BEACH POINT RAW GROUNDWATER TOXICITY  
TEST DATA (TEST NO. 3) - SURVIVAL AFTER 48 HOURS OF  
EXPOSURE

Concentration (% Groundwater by Volume)	Number Tested	No. Alive at 48 Hours	Percent Alive
UMD/WREC Control	10	10	100
10	10	10	100
18	10	10	100
32	10	10	100
56	10	10	100
100	10	0	0

TABLE A23-3. CLADOCERAN BEACH POINT RAW GROUNDWATER TOXICITY DATA (TEST NO. 3) - SURVIVAL OF ADULTS, NUMBER OF YOUNG PRODUCED PER BROOD, TOTAL NUMBER OF YOUNG, AND MEAN NUMBER OF YOUNG PER BROOD AFTER 7 DAYS OF EXPOSURE

Conc (% by Vol)	Rep	Brood No. 1	Brood No. 2	Brood No. 3	Total Young	Mean Young Per Brood
UMD/WREC Control	1	3	10	14	27	9.0
	2	5	8	12	25	8.3
	3	5	9	12	26	8.7
	4	3	9	14	26	8.7
	5	4	10	15	29	9.7
	6	4	9	14	27	9.0
	7	4	8	12	24	8.0
	8	4	8	13	25	8.3
	9	4	9	14	27	9.0
	10	3	10	13	26	8.7
APG-EA Diluent Water	1	3	7	13	23	7.7
	2	3	8	14	25	8.3
	3	3	6	14	23	7.7
	4	4	8	15	27	9.0
	5	3	7	14	24	8.0
	6	3	6	15	24	8.0
	7	4	6	14	24	8.0
	8	3	7	16	26	8.7
	9	3	7	16	26	8.7
	10	3	8	14	25	8.3
10	1	4	9	13	26	8.7
	2	3	9	13	25	8.3
	3	3	8	14	25	8.3
	4	3	9	13	25	8.3
	5	4	10	9	23	7.7
	6	3	10	16	29	9.7
	7	3	9	12	24	8.0
	8	3	9	14	26	8.7
	9	3	9	12	24	8.0
	10	3	8	13	24	8.0

TABLE A23-3. (CONTINUED)

Conc (% by Vol)	Rep	Brood No. 1	Brood No. 2	Brood No. 3	Total Young	Mean Young Per Brood
18	1	3	9	11	23	7.7
	2	3	9	12	24	8.0
	3	4	9	9	22	7.3
	4	3	8	11	22	7.3
	5	4	9	14	27	9.0
	6	3	7	9	19	6.3
	7	3	11	9	23	7.7
	8	3	11	12	26	8.7
	9	5	8	7	20	6.6
	10	3	7	9	19	6.3
32	1	3	8	11	22	7.3
	2	3	5	9	17	5.7
	3	1	1	2	4	1.3
	4	2	6	11	19	6.3
	5	2	7	10	19	6.3
	6	3	9	9	21	7.0
	7	2	5	15	22	7.3
	8	3	8	9	20	6.7
	9	2	6	13	21	7.0
	10	4	8	11	23	7.7
56	1	2	6	0	8	4.0
	2	2	4	11	17	5.7
	3	1	1	2	4	1.3
	4	1	6	4	11	3.7
	5	1	2	3	6	2.0
	6	5	4	0	9	4.5
	7	2	3	3	8	2.7
	8	2	3	3	8	2.7
	9	5	2	4	11	3.7
	10	1	0	0	1	1.0

TABLE A23-3. (CONTINUED)

Conc (% by Vol)	Rep	Brood No. 1	Brood No. 2	Brood No. 3	Total Young	Mean Young Per Brood
100	1	DEAD				
	2	DEAD				
	3	DEAD				
	4	DEAD				
	5	DEAD				
	6	DEAD				
	7	DEAD				
	8	DEAD				
	9	DEAD				
	10	DEAD				

TABLE A23-4. CLADOCERAN BEACH POINT RAW GROUNDWATER TOXICITY  
TEST STATISTICAL ANALYSIS (TEST NO. 3) - NEONATE  
PRODUCTION AFTER 7 DAYS OF EXPOSURE<sup>a</sup>

---

Data Transformation:

None

Chi-square Test for Normality:

Calculated test statistic:	1.19
Alpha value:	0.01
Critical value:	13.28
Conclusion	Fail to reject the null hypothesis that the data are normally distribute

Bartlett's Test for Homogeneity of Variances:

Calculated test statistic:	20.83
Alpha value:	0.01
Critical value:	15.09
Conclusion	Reject the null hypothesis that the variances are homogenous

Steel's Many-One Rank Test:

Calculated test statistic:	See Table A23-5
Alpha value:	0.05
Critical value:	75.0
Conclusion:	Reject the null hypothesis that all groups are equal

---

<sup>a</sup> The 100% raw Beach Point groundwater treatment was not included in the statistical analyses because all organisms died during the test.

TABLE A23-5. CLADOCERAN BEACH POINT RAW GROUNDWATER TOXICITY  
TEST STATISTICAL ANALYSIS (TEST NO. 3) - RESULTS OF  
STEEL'S MANY-ONE RANK TEST ON MEAN NEONATE  
PRODUCTION AFTER 7 DAYS OF EXPOSURE

Conc (% by Vol)	No. of Reps	Mean No. Neonates Produced	Rank Sum	Significance
UMD/WREC Control	10	26.2		
APG-EA Diluent Water	10	24.9	79.0	
10	10	25.1	81.0	
18	10	22.5	67.5	*
32	10	20.1	57.0	*
56	10	8.3	55.0	*

\* Significantly different at  $\alpha = 0.05$  (Steel's critical  
value = 75.0).



## APPENDIX 24

### CLADOCERAN ACUTE AND 7-DAY SURVIVAL AND REPRODUCTION TEST CONDUCTED ON BEACH POINT BUFFERED (pH $\approx$ 7) GROUNDWATER (WELL CC-33B) (TEST NO. 3)

Test Method:	EPA/600/4-89/001 (Weber et al., 1989)
Type of Test:	Static renewal (every 24 h)
Date:	August 24-31, 1993
Investigator:	S. D. Turley
Laboratory:	UMD/WREC
Groundwater:	
Source:	APG-EA Beach Point Well CC-33B
Chemical Characteristics:	See Appendix 48
Dilution Water:	
Source:	20% Perrier: 80% RO water
Chemical Characteristics:	See Table A24-1
Test Organism:	
Scientific Name:	<u>Ceriodaphnia dubia</u>
Age at Start of Test:	<4 h
Source:	UMD/WREC culture
Experimental Chambers:	
Material:	50 mL glass beaker
Test Solution Volume:	25 mL
No. Organisms/Replicate:	1
No. Organisms/Treatment:	10
Loading:	1 organism/beaker
Lighting:	Fluorescent; 60-85 foot candles
Aeration:	Prior to each renewal
pH Buffer:	10 N NaOH

Endpoints:

Mortality of adults; number of  
neonates produced in 3 broods

Water Quality:

Table A24-1

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Results:

Mortality:

48-h Exposure:

The data for the 48-h LC50 were obtained from the 7-d study. Forty percent of the organisms died in the 100% buffered groundwater concentration (Table A24-2); the organisms in all other treatments lived. Because <50% mortality occurred at the highest concentration studied, a 48-h LC50 could not be calculated.

7-d Exposure:

Significant ( $\alpha = 0.05$ ) mortality occurred to the daphnids exposed to 100% buffered groundwater by volume; survival was not affected by exposure to concentrations up to 56% buffered groundwater by volume (see Tables A24-3, A24-4, and A24-5). The 7-d LC50 for adult mortality could not be determined by the moving average angle method because 50% mortality occurred at the highest test concentration.

Neonate Production:

Buffered groundwater significantly ( $\alpha = 0.05$ ) reduced neonate production relative to the controls down to 18% buffered groundwater by volume (see Tables A24-3, A24-6, and A24-7). The NOEC and LOEC for the daphnids, based on reduced neonate production, are as follows:

NOEC = 10% raw groundwater by volume.

LOEC = 18% raw groundwater by volume.

TABLE A24-1. SUMMARY OF THE BEACH POINT BUFFERED GROUNDWATER  
BIOASSAY WATER QUALITY DATA FOR THE CLADOCERAN 7-  
DAY TEST (TEST NO. 3) - DISSOLVED OXYGEN (MG/L)

		<u>Test Concentrations (Percent Groundwater by Volume)</u>					
		0	10	18	32	56	100
<u>Day 0</u>							
0 H		8.2	8.0	8.0	7.9	7.8	5.2
<u>Day 1</u>							
0 H		8.1	8.1	8.1	8.0	8.0	5.9
24 H		8.0	7.4	7.6	7.4	7.5	7.6
<u>Day 2</u>							
0 H		8.1	8.1	8.1	8.0	7.9	7.6
24 H		7.5	7.8	7.9	8.0	7.9	7.1
<u>Day 3</u>							
0 H		8.2	8.0	8.0	7.9	7.8	7.6
24 H		7.1	7.2	7.1	7.5	7.4	7.3
<u>Day 4</u>							
0 H		7.7	7.9	7.9	7.8	7.7	7.5
24 H		7.7	7.6	7.5	7.3	7.5	7.4
<u>Day 5</u>							
0 H		8.2	7.8	7.9	7.9	7.8	7.6
24 H		7.3	7.0	7.1	7.0	7.1	7.1
<u>Day 6</u>							
0 H		8.4	7.8	7.7	7.6	7.2	5.0
24 H		7.6	7.7	7.6	7.6	7.7	7.7
<u>Day 7</u>							
24 H		8.2	8.0	8.0	8.0	7.8	8.0

TABLE A24-1. (CONTINUED) - pH (STANDARD UNITS)

	<u>Test Concentrations (Percent Groundwater by Volume)</u>					
	0	10	18	32	56	100
<u>Day 0</u>						
0 H	7.64	7.53	7.63	7.68	7.64	7.68
<u>Day 1</u>						
0 H	7.69	7.59	7.69	7.79	7.71	7.78
24 H	7.97	8.01	8.01	8.06	8.07	8.22
<u>Day 2</u>						
0 H	7.83	7.50	7.58	7.56	7.53	7.69
24 H	7.46	7.71	7.86	8.01	8.07	8.01
<u>Day 3</u>						
0 H	7.75	7.80	7.92	7.94	7.90	7.87
24 H	8.09	7.98	8.02	8.08	8.17	8.21
<u>Day 4</u>						
0 H	7.84	7.57	7.73	7.81	7.80	7.71
24 H	7.50	7.72	7.80	7.93	8.05	8.14
<u>Day 5</u>						
0 H	7.57	7.63	7.78	7.81	7.86	7.67
24 H	7.54	7.68	7.82	7.91	8.02	8.14
<u>Day 6</u>						
0 H	7.31	7.54	7.60	7.79	7.85	7.75
24 H	7.94	7.84	7.90	7.97	8.07	8.21
<u>Day 7</u>						
24 H	8.03	7.35	7.62	7.73	7.86	8.01

TABLE A24-1. (CONTINUED) - CONDUCTIVITY ( $\mu$ MHOS/CM)

	<u>Test Concentrations (Percent Groundwater by Volume)</u>	
	0	100
<u>Day 0</u>		
0 H	150	2000
<u>Day 1</u>		
0 H	140	1900
<u>Day 2</u>		
0 H	160	1950
<u>Day 3</u>		
0 H	150	1900
<u>Day 4</u>		
0 H	150	1900
<u>Day 5</u>		
0 H	150	1850
<u>Day 6</u>		
0 H	150	1925
<u>Day 7</u>		
24 H	150	1825

TABLE A24-1. (CONTINUED) - ALKALINITY (MG/L AS CaCO<sub>3</sub>)

	<u>Test Concentrations (Percent Groundwater by Volume)</u>	
	0	100
<u>Day 0</u>		
0 H	40	95
<u>Day 1</u>		
0 H	40	100
<u>Day 2</u>		
0 H	60	95
<u>Day 3</u>		
0 H	45	100
<u>Day 4</u>		
0 H	55	95
<u>Day 5</u>		
0 H	50	100
<u>Day 6</u>		
0 H	60	110
<u>Day 7</u>		
24 H	55	110

TABLE A24-1. (CONTINUED) - HARDNESS (MG/L AS CaCO<sub>3</sub>)

<u>Test Concentrations (Percent Groundwater by Volume)</u>		
	<u>0</u>	<u>100</u>
<u>Day 0</u>		
0 H	54	220
<u>Day 1</u>		
0 H	50	230
<u>Day 2</u>		
0 H	62	220
<u>Day 3</u>		
0 H	50	240
<u>Day 4</u>		
0 H	56	228
<u>Day 5</u>		
0 H	52	232
<u>Day 6</u>		
0 H	50	164
<u>Day 7</u>		
24 H	62	164

TABLE A24-2. CLADOCERAN BEACH POINT RAW GROUNDWATER TOXICITY  
TEST DATA (TEST NO. 3) - SURVIVAL AFTER 48 HOURS OF  
EXPOSURE

Concentration (% Groundwater by Volume)	Number Tested	No. Alive at 48 Hours	Percent Alive
UMD/WREC Control	10	10	100
10	10	10	100
18	10	10	100
32	10	10	100
56	10	10	100
100	10	6	60



TABLE A24-3. CLADOCERAN BEACH POINT BUFFERED GROUNDWATER TOXICITY DATA (TEST NO.3) - SURVIVAL OF ADULTS, NUMBER OF YOUNG PRODUCED PER BROOD, TOTAL NUMBER OF YOUNG, AND MEAN NUMBER OF YOUNG PRODUCED PER BROOD AFTER 7 DAYS OF EXPOSURE

Conc (% by Vol)	Rep	Brood No. 1	Brood No. 2	Brood No. 3	Total Young	Mean Young Per Brood
UMD/WREC Control	1	3	10	14	27	9.0
	2	5	8	12	25	8.3
	3	5	9	12	26	8.7
	4	3	9	14	26	8.7
	5	4	10	15	29	9.7
	6	4	9	14	27	9.0
	7	4	8	12	24	8.0
	8	4	8	13	25	8.3
	9	4	9	14	27	9.0
	10	3	10	13	26	8.7
10	1	6	5	14	25	8.3
	2	4	6	15	25	8.3
	3	8	5	16	29	9.7
	4	5	6	13	24	8.0
	5	3	7	15	25	8.3
	6	8	5	16	29	9.7
	7	3	6	15	24	8.0
	8	4	7	14	25	8.3
	9	3	7	16	26	8.7
	10	6	5	13	24	8.0
18	1	6	4	0	10	5.0
	2	6	2	0	8	4.0
	3	5	0	0	5	5.0
	4	5	0	0	5	5.0
	5	5	0	0	5	5.0
	6	4	0	0	4	4.0
	7	5	0	0	5	5.0
	8	5	0	0	5	5.0
	9	6	4	0	10	5.0
	10	5	0	0	5	5.0

TABLE A24-3. (CONTINUED)

Conc (% by Vol)	Rep	Brood No. 1	Brood No. 2	Brood No. 3	Total Young	Mean Young Per Brood
32	1	5	0	0	5	5.0
	2	4	0	0	4	4.0
	3	4	0	0	4	4.0
	4	4	0	0	4	4.0
	5	3	0	0	3	3.0
	6	4	0	0	0	4.0
	7	3	0	0	3	3.0
	8	4	0	DEAD	4	4.0
	9	5	0	0	5	5.0
	10	3	0	0	3	3.0
56	1	2	0	0	2	2.0
	2	6	4	0	10	5.0
	3	6	0	0	6	6.0
	4	3	0	0	3	3.0
	5	3	2	0	5	2.5
	6	2	0	0	2	2.0
	7	5	0	0	5	5.0
	8	3	0	DEAD	3	3.0
	9	2	0	0	2	2.0
	10	1	0	0	1	1.0
100	1	2	0	0	2	2.0
	2	DEAD				
	3	DEAD				
	4	3	0	0	3	3.0
	5	DEAD				
	6	0	0	0	0	0.0
	7	4	0	0	4	4.0
	8	0	0	0	0	0.0
	9	DEAD				
	10	DEAD				

TABLE A24-4. CLADOCERAN BEACH POINT BUFFERED GROUNDWATER  
TOXICITY TEST STATISTICAL ANALYSIS (TEST NO. 3) -  
ADULT SURVIVAL AFTER 7 DAYS OF EXPOSURE

---

Data Transformation:

None

Fisher's Exact Test:

Calculated test statistic:	See Table A24-5
Alpha value:	0.05
Critical value:	6
Conclusion:	Reject the null hypothesis that all groups are equal.

---

TABLE A24-5. CLADOCERAN BEACH POINT BUFFERED GROUNDWATER  
TOXICITY TEST STATISTICAL ANALYSIS (TEST NO. 3) -  
RESULTS OF FISHER'S EXACT TEST ON ADULT SURVIVAL  
AFTER 7 DAYS OF EXPOSURE

Conc (% by Vol)	Number Alive	Number Dead	b Value	Significance
UMD/WREC Control	10	0		
10	10	0	10	
18	10	0	10	
32	10	1	9	
56	10	1	9	
100	5	5	5	*

\* Significantly different at  $\alpha = 0.05$  (Fisher's critical value = 6).

TABLE A24-6. CLADOCERAN BEACH POINT BUFFERED GROUNDWATER  
TOXICITY TEST STATISTICAL ANALYSIS (TEST NO. 3) -  
NEONATE PRODUCTION AFTER 7 DAYS OF EXPOSURE<sup>a</sup>

---

Data Transformation:

None

Chi-Square Test for Normality:

Calculated test statistic:	11.50
Alpha value:	0.01
Critical value:	13.28
Conclusion:	Fail to reject the null hypothesis that the data are normally distributed

Bartlett's Test for Homogeneity of Variances:

Calculated test statistic:	13.77
Alpha value:	0.01
Critical value:	13.28
Conclusion:	Reject the null hypothesis that the variances are homogenous

Steel's Many-One Rank Test:

Calculated test statistics:	See Table A24-7
Alpha value:	0.05
Critical value:	76.0
Conclusion:	Reject the null hypothesis that all groups are equal

---

<sup>a</sup> The 100% buffered Beach Point groundwater treatment was not included in the statistical analyses because all concentrations above the NOEC for survival are excluded from the hypothesis test for reproductive effects.

TABLE A24-7. CLADOCERAN BEACH POINT BUFFERED GROUNDWATER TOXICITY STATISTICAL ANALYSIS (TEST NO. 3) - RESULTS OF STEEL'S MANY-ONE RANK TEST ON MEAN NEONATE PRODUCTION AFTER 7 DAYS OF EXPOSURE

Conc (% by Vol)	No. of Reps	Mean No. Neonates Produced	Rank Sum	Significance
UMD/WREC Control	10	26.2		
10	10	24.9	77.0	
18	10	6.2	55.0	*
32	9	3.9	55.0	*
56	9	3.9	55.0	*

\* Significantly different at  $\alpha = 0.05$  (Steel's critical value = 76.0).

## APPENDIX 25

### CLADOCERAN ACUTE AND 7-DAY SURVIVAL AND REPRODUCTION TEST CONDUCTED ON BEACH POINT RAW (pH $\approx$ 4) GROUNDWATER (WELL CC-33B) (TEST NO. 4)

Test Method:	EPA/600/4-89/001 (Weber et al., 1989)
Type of Test:	Static renewal (every 24 h)
Date:	November 30- December 7, 1993
Investigator:	S.D. Turley
Laboratory:	UMD/WREC
Groundwater:	
Source:	APG-EA Beach Point Well CC-33B
Chemical Characteristics:	See Appendix 48
Dilution Water:	
Source:	20% Perrier: 80% RO water
Chemical Characteristics:	See Table A25-1
Test Organism:	
Scientific Name:	<u>Ceriodaphnia dubia</u>
Age at Start of Test:	<4 h
Source:	UMD/WREC culture
Experimental Chambers:	
Material:	50 mL glass beaker
Test Solution Volume:	25 mL
No. Organisms/Replicate:	1
No. Organisms/Treatment:	10
Loading:	1 organism/beaker
Lighting:	Fluorescent; 60-85 foot candles
Aeration:	Prior to each renewal
Endpoints:	Mortality of adults; number of

neonates produced in 3 broods

Water Quality:

Table A25-1

---

Results:

Mortality:

48-h Exposure:

The data for the 48-h LC50 were obtained from the 7-d study. All organisms exposed to 100% raw groundwater died during the 48-h exposure (Table A25-2). Twenty percent died at the next dilution of 56% groundwater by volume. No organisms died in the remaining treatments. The 48-h LC50, which was determined by the moving average angle method, is as follows:

48-h LC50 = 62.8% raw groundwater by volume (95% confidence limits = 54.99-73.69).

7-d Exposure:

All organisms exposed to 100% raw groundwater died during the 7-d exposure (Table A25-3). Survival was significantly ( $\alpha = 0.05$ ) reduced by exposure to concentrations of 32% and 56% raw groundwater by volume (Tables A25-4 and A25-5). The 7-d LC50, which was determined by the moving average angle method, is as follows:

7-d LC50 = 42.3% raw groundwater by volume (95% confidence limits = 33.51-53.47).

Neonate Production:

Raw groundwater significantly ( $\alpha = 0.05$ ) reduced neonate production relative to the controls down to 18% raw groundwater by volume (see Tables A25-3, A25-6, and A25-7). The NOEC and LOEC for the daphnids, based on reduced neonate production, are as follows:

NOEC = 10% raw groundwater by volume.

LOEC = 18% raw groundwater by volume.



TABLE A25-1. SUMMARY OF THE BEACH POINT RAW GROUNDWATER BIOASSAY  
WATER QUALITY DATA FOR THE CLADOCERAN 7-DAY TEST  
(TEST NO. 4) - DISSOLVED OXYGEN (MG/L)

		<u>Test Concentrations (Percent Groundwater by Volume)</u>					
		0	10	18	32	56	100
<u>Day 0</u>							
0 H		8.4	8.6	8.6	8.2	8.6	7.7
<u>Day 1</u>							
0 H		8.7	8.4	8.4	8.2	8.1	7.4
24 H		8.8	9.0	9.0	9.1	8.9	8.8
<u>Day 2</u>							
0 H		8.5	8.3	8.3	8.7	8.7	
24 H		8.6	8.7	8.7	8.8	8.6	
<u>Day 3</u>							
0 H		8.3	7.9	8.3	8.2	8.5	
24 H		8.5	8.3	8.8	8.8	8.7	
<u>Day 4</u>							
0 H		8.5	8.4	8.4	8.3	8.5	
24 H		8.6	8.5	8.7	8.6	8.6	
<u>Day 5</u>							
0 H		8.1	8.2	8.1	8.4	8.2	
24 H		8.5	8.7	8.5	8.7	8.4	
<u>Day 6</u>							
0 H		8.6	8.5	8.5	8.4	8.4	
24 H		8.1	8.4	8.3	8.6	8.5	
<u>Day 7</u>							
24 H		8.0	8.3	8.2	8.3	8.3	

TABLE A25-1 (CONTINUED) - pH (STANDARD UNITS)

	<u>Test Concentrations (Percent Groundwater by Volume)</u>					
	0	10	18	32	56	100
<u>Day 0</u>						
0 H	6.50	6.56	6.50	6.37	6.26	4.01
<u>Day 1</u>						
0 H	7.65	7.61	7.42	7.08	6.70	3.97
24 H	7.84	7.95	7.98	8.04	7.91	
<u>Day 2</u>						
0 H	7.70	7.83	7.37	6.72	6.40	3.97
24 H	7.68	8.06	8.16	8.20	8.15	
<u>Day 3</u>						
0 H	7.51	7.43	7.35	7.07	6.57	3.91
24 H	7.78	8.05	8.19	8.24	8.14	
<u>Day 4</u>						
0 H	7.66	7.73	7.62	7.14	6.76	3.99
24 H	7.77	8.03	8.08	8.05	8.02	
<u>Day 5</u>						
0 H	7.87	7.88	7.78	7.52	6.99	3.85
24 H	7.84	7.88	7.86	7.84	7.78	
<u>Day 6</u>						
0 H	7.71	7.48	7.35	7.33	6.80	3.88
24 H	8.02	8.32	8.41	8.47	8.40	
<u>Day 7</u>						
24 H	8.09	8.01	7.92	7.84	7.76	

TABLE A25-1. (CONTINUED) - CONDUCTIVITY ( $\mu$ MHOS/CM)

<u>Test Concentrations (Percent Groundwater by Volume)</u>		
	<u>0</u>	<u>100</u>
<u>Day 0</u>		
0 H	235	1750
<u>Day 1</u>		
0 H	220	1700
<u>Day 2</u>		
0 H	230	1800
<u>Day 3</u>		
0 H	220	1700
<u>Day 4</u>		
0 H	220	1750
<u>Day 5</u>		
0 H	200	1700
<u>Day 6</u>		
0 H	220	1750
<u>Day 7</u>		
24 H	220	1700

TABLE A25-1. (CONTINUED) - ALKALINITY (MG/L AS CaCO<sub>3</sub>)

	<u>Test Concentrations (Percent Groundwater by Volume)</u>	
	<u>0</u>	<u>100</u>
<u>Day 0</u>		
0 H	60	<sup>a</sup>
<u>Day 1</u>		
0 H	55	<sup>a</sup>
<u>Day 2</u>		
0 H	50	
<u>Day 3</u>		
0 H	50	
<u>Day 4</u>		
0 H	55	
<u>Day 5</u>		
0 H	50	
<u>Day 6</u>		
0 H	50	
<u>Day 7</u>		
24 H	55	

<sup>a</sup> Could not obtain measurement.

TABLE A25-1. (CONTINUED) - HARDNESS (MG/L AS CaCO<sub>3</sub>)

<u>Test Concentrations (Percent Groundwater by Volume)</u>		
	<u>0</u>	<u>100</u>
<u>Day 0</u>		
0 H	80	a
<u>Day 1</u>		
0 H	70	a
<u>Day 2</u>		
0 H	64	
<u>Day 3</u>		
0 H	70	
<u>Day 4</u>		
0 H	60	
<u>Day 5</u>		
0 H	60	
<u>Day 6</u>		
0 H	80	
<u>Day 7</u>		
24 H	70	

<sup>a</sup> Could not obtain measurement.

TABLE A25-2. CLADOCERAN BEACH POINT RAW GROUNDWATER TOXICITY  
TEST DATA (TEST NO. 4) - SURVIVAL AFTER 48 HOURS OF  
EXPOSURE

Concentration (% Groundwater by Volume)	Number Tested	No. Alive at 48 Hours	Percent Alive
UMD/WREC Control	10	10	100
10	10	10	100
18	10	10	100
32	10	10	100
56	10	8	80
100	10	0	0

TABLE A25-3. CLADOCERAN BEACH POINT RAW GROUNDWATER TOXICITY DATA (TEST NO. 4) - SURVIVAL OF ADULTS, NUMBER OF YOUNG PRODUCED PER BROOD, TOTAL NUMBER OF YOUNG, AND MEAN NUMBER OF YOUNG PER BROOD AFTER 7 DAYS OF EXPOSURE

Conc (% by Vol)	Rep	Brood No. 1	Brood No. 2	Brood No. 3	Total Young	Mean Young Per Brood
UMD/WREC Control	1	6	11	20	37	12.3
	2	5	10	15	30	10.0
	3	5	9	13	27	9.0
	4	4	9	14	27	9.0
	5	4	10	13	27	9.0
	6	5	11	12	28	9.3
	7	4	15	14	33	11.0
	8	4	10	17	31	10.3
	9	4	11	19	34	11.3
	10	5	12	11	28	9.3
APG-EA Diluent Water	1	5	9	15	29	9.7
	2	3	7	19	29	9.7
	3	3	8	16	27	9.0
	4	5	9	14	28	9.3
	5	4	10	17	31	10.3
	6	4	11	17	32	10.7
	7	5	8	15	28	9.3
	8	6	9	12	27	9.0
	9	4	10	16	30	10.0
	10	4	14	14	32	10.7
10	1	4	8	18	30	10.0
	2	4	9	19	32	10.7
	3	4	9	17	30	10.0
	4	4	8	17	29	9.7
	5	4	8	17	29	9.7
	6	4	8	18	30	10.0
	7	5	10	18	33	11.0
	8	4	8	17	29	9.7
	9	3	9	19	31	10.3
	10	4	9	18	31	10.3

TABLE A25-3. (CONTINUED)

Conc (% by Vol)	Rep	Brood No. 1	Brood No. 2	Brood No. 3	Total Young	Mean Young Per Brood
18	1	0	10	12	22	11.0
	2	0	7	9	16	8.0
	3	4	8	10	22	7.3
	4	0	8	8	16	8.0
	5	4	7	8	19	6.3
	6	4	8	9	21	7.0
	7	4	6	8	18	6.0
	8	4	7	7	18	6.0
	9	5	7	8	20	6.7
	10	3	7	11	21	7.0
32	1	4	DEAD	0	4	4.0
	2	0	0	DEAD	0	0.0
	3	3	DEAD	0	3	3.0
	4	2	0	0	2	2.0
	5	3	1	0	4	2.0
	6	4	2	0	6	3.0
	7	3	DEAD	0	3	3.0
	8	0	0	7	7	7.0
	9	3	DEAD	0	3	3.0
	10	3	2	0	5	2.5
56	1	0	0	0	0	0.0
	2	3	0	0	3	3.0
	3	1	DEAD	0	1	1.0
	4	0	0	0	0	0.0
	5	0	DEAD	0	0	0.0
	6	0	DEAD	0	0	0.0
	7	0	DEAD	0	0	0.0
	8	0	0	0	0	0.0
	9	0	0	0	0	0.0
	10	DEAD	0	0	0	0.0



TABLE A25-3. (CONTINUED)

Conc (% by Vol)	Rep	Brood No. 1	Brood No. 2	Brood No. 3	Total Young	Mean Young Per Brood
100	1	DEAD				
	2	DEAD				
	3	DEAD				
	4	DEAD				
	5	DEAD				
	6	DEAD				
	7	DEAD				
	8	DEAD				
	9	DEAD				
	10	DEAD				

TABLE A25-4. CLADOCERAN BEACH POINT RAW GROUNDWATER TOXICITY  
TEST STATISTICAL ANALYSIS (TEST NO. 4) - ADULT  
SURVIVAL AFTER 7 DAYS OF EXPOSURE

---

Data Transformation:

None

Fisher's Exact Test:

Calculated test statistic:	See Table A25-5
Alpha value:	0.05
Critical value:	6
Conclusion:	Reject the null hypothesis that all groups are equal.

---

TABLE A25-5. CLADOCERAN BEACH POINT RAW GROUNDWATER TOXICITY  
TEST STATISTICAL ANALYSIS (TEST NO. 4) - RESULTS  
OF FISHER'S EXACT TEST ON ADULT SURVIVAL AFTER 7  
DAYS OF EXPOSURE

Conc (% by	Number Alive	Number Dead	b Value	Significance
UMD/WREC Control	10	0		
APG-EA Diluent Water	10	0	10	
10	10	0	10	
18	10	0	10	
32	5	5	5	*
56	5	5	5	*

\* Significantly different at  $\alpha = 0.05$  (Fisher's critical  
value = 6).

TABLE A25-6. CLADOCERAN BEACH POINT RAW GROUNDWATER TOXICITY  
TEST STATISTICAL ANALYSIS (TEST NO. 4) - NEONATE  
PRODUCTION AFTER 7 DAYS OF EXPOSURE<sup>a</sup>

---

Data Transformation:

None

Chi-square Test for Normality:

Calculated test statistic:	8.36
Alpha value:	0.01
Critical value:	13.28
Conclusion	Fail to reject the null hypothesis that the data are normally distributed

Bartlett's Test for Homogeneity of Variances:

Calculated test statistic:	7.30
Alpha value:	0.01
Critical value:	11.34
Conclusion	Fail to reject the null hypothesis that the variances are homogenous

ANOVA:

Calculated test statistic:	48.70
Alpha value:	0.05
Critical value:	2.92
Conclusion:	Reject the null hypothesis that all groups are equal

Dunnett's Test:

Calculated test statistic:	See Table A25-7
Alpha value:	0.05
Critical value:	2.15
Conclusion:	Reject the null hypothesis that all groups are equal

---

<sup>a</sup> The 32%, 56% and 100% concentrations of Beach Point raw groundwater were not included in the statistical analyses because significant mortality occurred at these concentrations during the test.

TABLE A25-7. CLADOCERAN BEACH POINT RAW GROUNDWATER TOXICITY  
TEST STATISTICAL ANALYSIS (TEST NO. 4) - RESULTS OF  
DUNNETT'S TEST ON MEAN NEONATE PRODUCTION AFTER 7  
DAYS OF EXPOSURE

Conc (% by Vol)	No. of Reps	Mean No. Neonates Produced	T-Stat	Significance
UMD/WREC Control	10	30.2		
APG-EA Diluent Water	10	29.7	0.456	
10	10	30.4	-0.182	
18	10	19.3	9.945	*

\* Significantly different at alpha = 0.05 (Dunnett's critical  
value = 2.15).

## APPENDIX 26

### CLADOCERAN ACUTE AND 7-DAY SURVIVAL AND REPRODUCTION TEST CONDUCTED ON BEACH POINT BUFFERED (pH $\approx$ 7) GROUNDWATER (WELL CC-33B) (TEST NO. 4)

Test Method: EPA/600/4-89/001  
(Weber et al., 1989)

Type of Test: Static renewal (every 24 h)

Date: November 30 - December 7, 1993

Investigator: S. D. Turley

Laboratory: UMD/WREC

Groundwater:

Source: APG-EA Beach Point Well CC-33B

Chemical Characteristics: See Appendix 48

Dilution Water:

Source: 20% Perrier: 80% RO water

Chemical Characteristics: See Table A26-1

Test Organism:

Scientific Name: Ceriodaphnia dubia

Age at Start of Test: <4 h

Source: UMD/WREC culture

Experimental Chambers:

Material: 50 mL glass beaker

Test Solution Volume: 25 mL

No. Organisms/Replicate: 1

No. Organisms/Treatment: 10

Loading: 1 organism/beaker

Lighting: Fluorescent; 60-85 foot  
candles

Aeration: Prior to each renewal

pH Buffer: 10 N NaOH

Endpoints:

Mortality of adults; number of neonates produced in 3 broods

Water Quality:

Table A26-1

---

Results:

Mortality:

48-h Exposure:

The data for the 48-h LC50 were obtained from the 7-d study. Fifty percent of the organisms died in the 100% buffered groundwater concentration (Table A26-2); twenty percent died at both 56 and 32% groundwater by volume. No mortality occurred in the remaining treatments. Because 50% mortality occurred at the highest concentration studied, a 48-h LC50 could not be calculated.

7-d Exposure:

All organisms exposed to 100% buffered groundwater died during the 7-d exposure (Table A26-3). Survival was significantly ( $\alpha = 0.05$ ) reduced by exposure to concentrations of 32% and 56% buffered groundwater by volume (Tables A26-4 and A26-5). The 7-d LC50, which was determined by the moving average angle method, is as follows:

7-d LC50 = 39.8% buffered groundwater by volume (95% confidence limits = 29.74-51.98).

Neonate Production:

Buffered groundwater significantly ( $\alpha = 0.05$ ) reduced neonate production relative to the controls down to 18% buffered groundwater by volume (see Tables A26-3, A26-6, and A26-7). The NOEC and LOEC for the daphnids, based on reduced neonate production, are as follows:

NOEC = 10% raw groundwater by volume.

LOEC = 18% raw groundwater by volume.

TABLE A26-1. SUMMARY OF THE BEACH POINT BUFFERED GROUNDWATER  
BIOASSAY WATER QUALITY DATA FOR THE CLADOCERAN 7-  
DAY TEST (TEST NO. 4) - DISSOLVED OXYGEN (MG/L)

	<u>Test Concentrations (Percent Groundwater by Volume)</u>					
	0	10	18	32	56	100
<u>Day 0</u>						
0 H	8.4	8.5	8.6	8.2	8.2	7.6
<u>Day 1</u>						
0 H	8.7	8.3	8.3	8.4	8.2	7.8
24 H	8.8	8.9	9.0	8.8	8.6	8.8
<u>Day 2</u>						
0 H	8.5	8.4	8.3	8.2	8.1	7.5
24 H	8.6	8.7	8.7	8.7	8.7	8.8
<u>Day 3</u>						
0 H	8.3	8.6	8.7	8.4	8.5	7.5
24 H	8.5	8.8	8.9	8.8	8.8	8.8
<u>Day 4</u>						
0 H	8.5	8.7	8.5	8.3	8.2	7.7
24 H	8.5	8.6	8.7	8.4	8.2	8.6
<u>Day 5</u>						
0 H	8.1	8.5	8.6	8.3	8.2	7.8
24 H	8.5	8.6	8.4	8.6	8.4	8.6
<u>Day 6</u>						
0 H	8.6	8.3	8.4	8.0	8.4	8.5
24 H	8.1	8.5	8.4	8.5	8.4	
<u>Day 7</u>						
24 H	8.0	8.4	8.3	8.4	8.2	



TABLE A26-1. (CONTINUED) - pH (STANDARD UNITS)

		<u>Test Concentrations (Percent Groundwater by Volume)</u>					
		0	10	18	32	56	100
<u>Day 0</u>							
0 H		6.50	6.71	6.69	6.60	6.85	7.08
<u>Day 1</u>							
0 H		7.65	7.65	7.80	7.82	7.85	7.59
24 H		7.84	8.12	8.28	8.34	8.30	8.24
<u>Day 2</u>							
0 H		7.70	7.40	7.64	7.81	7.79	7.47
24 H		7.68	8.33	8.53	8.58	8.61	8.51
<u>Day 3</u>							
0 H		7.51	7.59	7.86	8.06	8.08	7.69
24 H		7.78	8.43	8.46	8.48	8.48	8.44
<u>Day 4</u>							
0 H		7.66	7.76	7.90	7.96	8.03	7.70
24 H		7.77	8.40	8.42	8.54	8.69	8.63
<u>Day 5</u>							
0 H		7.87	7.88	7.99	8.01	8.06	7.11
24 H		7.34	8.16	8.26	8.37	8.60	8.68
<u>Day 6</u>							
0 H		7.71	7.56	7.66	7.69	7.70	7.39
24 H		8.02	8.70	8.83	8.83	8.87	
<u>Day 7</u>							
24 H		8.09	7.89	7.87	7.93	8.03	

TABLE A26-1. (CONTINUED) - CONDUCTIVITY ( $\mu$ MHOS/CM)

	<u>Test Concentrations (Percent Groundwater by Volume)</u>	
	0	100
<u>Day 0</u>		
0 H	235	1750
<u>Day 1</u>		
0 H	220	1650
<u>Day 2</u>		
0 H	230	1700
<u>Day 3</u>		
0 H	220	1700
<u>Day 4</u>		
0 H	220	1750
<u>Day 5</u>		
0 H	200	1700
<u>Day 6</u>		
0 H	220	1750
<u>Day 7</u>		
24 H	210	1800

TABLE A26-1. (CONTINUED) - ALKALINITY (MG/L AS CaCO<sub>3</sub>)

	<u>Test Concentrations (Percent Groundwater by Volume)</u>	
	0	100
<u>Day 0</u>		
0 H	60	55
<u>Day 1</u>		
0 H	55	50
<u>Day 2</u>		
0 H	50	55
<u>Day 3</u>		
0 H	50	60
<u>Day 4</u>		
0 H	55	55
<u>Day 5</u>		
0 H	50	50
<u>Day 6</u>		
0 H	50	60
<u>Day 7</u>		
24 H	55	60

TABLE A26-1. (CONTINUED) - HARDNESS (MG/L AS  $\text{CaCO}_3$ )

	<u>Test Concentrations (Percent Groundwater by Volume)</u>	
	0	100
<u>Day 0</u>		
0 H	80	210
<u>Day 1</u>		
0 H	70	200
<u>Day 2</u>		
0 H	64	200
<u>Day 3</u>		
0 H	70	210
<u>Day 4</u>		
0 H	60	220
<u>Day 5</u>		
0 H	60	220
<u>Day 6</u>		
0 H	80	198
<u>Day 7</u>		
24 H	68	214

TABLE A26-2. CLADOCERAN BEACH POINT RAW GROUNDWATER TOXICITY  
TEST DATA (TEST NO. 4) - SURVIVAL AFTER 48 HOURS OF  
EXPOSURE

Concentration (% Groundwater by Volume)	Number Tested	No. Alive at 48 Hours	Percent Alive
UMD/WREC Control	10	10	100
10	10	10	100
18	10	10	100
32	10	8	80
56	10	8	80
100	10	5	50

TABLE A26-3. CLADOCERAN BEACH POINT BUFFERED GROUNDWATER  
TOXICITY DATA (TEST NO.4) - SURVIVAL OF ADULTS,  
NUMBER OF YOUNG PRODUCED PER BROOD, TOTAL NUMBER OF  
YOUNG, AND MEAN NUMBER OF YOUNG PRODUCED PER BROOD  
AFTER 7 DAYS OF EXPOSURE

Conc (% by Vol)	Rep	Brood No. 1	Brood No. 2	Brood No. 3	Total Young	Mean Young Per Brood
UMD/WREC Control	1	6	11	20	37	12.3
	2	5	10	15	30	10.0
	3	5	9	13	27	9.0
	4	4	9	14	27	9.0
	5	4	10	13	27	9.0
	6	5	11	12	28	9.3
	7	4	15	14	33	11.0
	8	4	10	17	31	10.3
	9	4	11	19	34	11.3
	10	5	12	11	28	9.3
10	1	4	8	18	30	10.0
	2	3	7	19	29	9.7
	3	3	11	18	32	10.7
	4	4	9	18	31	10.3
	5	5	10	19	34	11.3
	6	4	8	17	29	9.7
	7	4	8	18	30	10.0
	8	4	8	20	32	10.7
	9	4	6	17	27	9.0
	10	4	8	20	32	10.7
18	1	0	0	9	9	9.0
	2	4	7	9	20	6.7
	3	0	7	9	16	8.0
	4	4	8	10	22	7.3
	5	3	14	0	17	8.5
	6	4	12	0	16	8.0
	7	3	8	9	20	6.7
	8	0	0	6	6	6.0
	9	3	8	9	20	6.7
	10	3	10	12	25	8.3

TABLE A26-3. (CONTINUED)

Conc (% by Vol)	Rep	Brood No. 1	Brood No. 2	Brood No. 3	Total Young	Mean Young Per Brood
32	1	3	5	7	15	5.0
	2	0	0	3	3	3.0
	3	3	0	6	9	4.5
	4	3	0	5	8	4.0
	5	3	3	DEAD	6	3.0
	6	DEAD	0	0	0	0.0
	7	DEAD	0	0	0	0.0
	8	4	0	DEAD	4	4.0
	9	DEAD	0	0	0	0.0
	10	0	5	2	7	3.5
56	1	DEAD	0	0	0	0.0
	2	DEAD	0	0	0	0.0
	3	0	DEAD	0	0	0.0
	4	DEAD	0	0	0	0.0
	5	0	DEAD	0	0	0.0
	6	DEAD	0	0	0	0.0
	7	0	0	0	0	0.0
	8	0	0	0	0	0.0
	9	3	4	0	7	3.5
	10	0	DEAD	0	0	0.0
100	1	DEAD				
	2	DEAD				
	3	DEAD				
	4	0	DEAD			
	5	DEAD				
	6	DEAD				
	7	DEAD				
	8	0	DEAD			
	9	DEAD				
	10	DEAD				

TABLE A26-4. CLADOCERAN BEACH POINT BUFFERED GROUNDWATER  
TOXICITY TEST STATISTICAL ANALYSIS (TEST NO. 4) -  
ADULT SURVIVAL AFTER 7 DAYS OF EXPOSURE

---

Data Transformation:

None

Fisher's Exact Test:

Calculated test statistic:	See Table A26-5
Alpha value:	0.05
Critical value:	6
Conclusion:	Reject the null hypothesis that all groups are equal.

---



TABLE A26-5. CLADOCERAN BEACH POINT BUFFERED GROUNDWATER  
TOXICITY TEST STATISTICAL ANALYSIS (TEST NO. 4) -  
RESULTS OF FISHER'S EXACT TEST ON ADULT SURVIVAL  
AFTER 7 DAYS OF EXPOSURE

Conc (% by Vol)	Number Alive	Number Dead	b Value	Significance
UMD/WREC Control	10	0		
10	10	0	10	
18	10	0	10	
32	5	5	5	*
56	3	7	3	*

\* Significantly different at  $\alpha = 0.05$  (Fisher's critical  
value = 6).

TABLE A26-6. CLADOCERAN BEACH POINT BUFFERED GROUNDWATER  
TOXICITY TEST STATISTICAL ANALYSIS (TEST NO. 4) -  
NEONATE PRODUCTION AFTER 7 DAYS OF EXPOSURE<sup>a</sup>

---

Data Transformation:

None

Chi-Square Test for Normality:

Calculated test statistic:	0.10
Alpha value:	0.01
Critical value:	13.28
Conclusion:	Fail to reject the null hypothesis that the data are normally distributed

Bartlett's Test for Homogeneity of Variances:

Calculated test statistic:	8.75
Alpha value:	0.01
Critical value:	13.28
Conclusion:	Fail to reject the null hypothesis that the variances are homogenous

ANOVA:

Calculated test statistic:	35.49
Alpha value:	0.05
Critical value:	3.35
Conclusion:	Reject the null hypothesis that all groups are equal

Dunnett's Test:

Calculated test statistics:	See Table A26-7
Alpha value:	0.05
Critical value:	2.01
Conclusion:	Reject the null hypothesis that all groups are equal

---

<sup>a</sup> The 32%, 56% and 100% buffered Beach Point groundwater treatments were not included in the statistical analyses because all concentrations above the NOEC for survival are excluded from the hypothesis test for reproductive effects.

TABLE A26-7. CLADOCERAN BEACH POINT BUFFERED GROUNDWATER  
TOXICITY STATISTICAL ANALYSIS (TEST NO. 4) -  
RESULTS OF DUNNETT'S TEST ON MEAN NEONATE  
PRODUCTION AFTER 7 DAYS OF EXPOSURE

Conc (% by Vol)	No. of Reps	Mean No. Neonates Produced	T-Stat	Significance
UMD/WREC Control	10	30.2		
10	10	30.6	-0.219	
18	10	17.1	7.184	*

\* Significantly different at alpha = 0.05 (Dunnett's critical  
value = 2.01).

## APPENDIX 27

### FATHEAD MINNOW ACUTE AND 7-DAY SURVIVAL AND GROWTH TEST CONDUCTED ON BEACH POINT RAW (pH $\approx$ 4) GROUNDWATER (WELL CC-33B) (TEST NO. 1)

Test Method:	EPA/600/4-89/001 (Weber et al., 1989)
Type of Test:	Static renewal (every 24 h)
Date:	April 7-14, 1993
Investigator:	S.D. Turley
Laboratory:	UMD/WREC
Groundwater:	
Source:	APG-EA Beach Point Well CC-33B
Chemical Characteristics:	See Appendix 48
Dilution Water:	
Source:	20% Perrier: 80% RO water
Chemical Characteristics:	See Table A27-1
Test Organism:	
Scientific Name:	<u>Pimephales promelas</u>
Dry Weight:	0.69 mg (mean weight of controls at end of test)
Age at Start of Test:	<24 h
Source:	UMD/WREC culture
Experimental Chambers:	
Material:	600 mL glass beaker
Test Solution Volume:	400 mL
No. Organisms/Replicate:	10
No. Organisms/Treatment:	40
Loading:	<0.5 g/L
Lighting:	Fluorescent; 60-85 foot candles

Aeration:	Prior to each renewal
Endpoints:	Mortality; growth
Water Quality:	Table A27-1

---

## Results:

### Mortality:

#### 96-h Exposure:

The data for the 96-h LC50 were obtained from the 7-d study. All organisms exposed to 100% raw groundwater died during the 96-h exposure (Table A27-2). One organism died at the next dilution of 56% groundwater by volume. No organisms died in the remaining treatments. The 96-h LC50, which was determined by the moving average angle method, is as follows:

96-h LC50 = 63.9% raw groundwater by volume (95% confidence limits = 60.34-68.07).

#### 7-d Exposure:

All organisms exposed to 100% raw groundwater died during the 7-d exposure (Table A27-3). Three organisms died at 56% groundwater by volume; one death occurred at 32% groundwater by volume. No organisms died in the remaining treatments. The 7-d LC50, which was determined by the moving average angle method, is as follows:

7-d LC50 = 61.7% raw groundwater by volume (95% confidence limits = 58.06-65.93).

### Growth:

A significant ( $\alpha = 0.05$ ) reduction in growth occurred in fathead minnow larvae exposed for 7 d to both 100% and 56% raw groundwater by volume (see Tables A27-3 A27-4, and A27-5). The NOEC and LOEC for the larval fish, based on reduced growth, are as follows:

NOEC = 32% raw groundwater by volume.

LOEC = 56% raw groundwater by volume.

TABLE A27-1. SUMMARY OF THE BEACH POINT RAW GROUNDWATER BIOASSAY  
TEST WATER QUALITY DATA FOR THE FATHEAD MINNOW 7-  
DAY TEST (TEST NO. 1) - DISSOLVED OXYGEN (MG/L)

<u>Test Concentrations (Percent Groundwater by Volume)</u>						
	0	10	18	32	56	100
<u>Day 0</u>						
0 H	8.8	8.7	8.6	8.3	8.3	8.2
<u>Day 1</u>						
0 H	8.7	8.6	8.5	8.5	8.5	5.8
24 H	8.1	8.0	7.9	8.0	8.0	8.2
<u>Day 2</u>						
0 H	8.1	7.6	7.6	7.5	7.5	
24 H	6.5	6.6	7.0	7.1	7.2	
<u>Day 3</u>						
0 H	8.5	8.4	8.3	8.3	8.3	
24 H	6.4	6.5	6.9	7.0	7.1	
<u>Day 4</u>						
0 H	8.6	8.4	8.4	8.2	8.2	
24 H	6.3	6.5	6.2	6.3	6.6	
<u>Day 5</u>						
0 H	8.2	8.1	8.0	8.0	7.5	
24 H	6.4	6.4	6.2	6.1	6.3	
<u>Day 6</u>						
0 H	8.0	8.1	8.0	8.0	7.8	
24 H	6.1	6.2	6.0	6.0	5.9	
<u>Day 7</u>						
24 H 6.7	6.7	6.6	6.6	6.6	6.6	

TABLE A27-1. (CONTINUED) - pH (STANDARD UNITS)

		<u>Test Concentrations (Percent Groundwater by Volume)</u>					
		0	10	18	32	56	100
<u>Day 0</u>							
0 H		6.71	6.69	6.43	6.20	5.93	3.95
<u>Day 1</u>							
0 H		6.46	6.45	6.46	6.42	5.64	3.74
24 H		6.63	6.73	6.80	6.84	6.84	4.80
<u>Day 2</u>							
0 H		7.30	7.11	6.80	6.51	6.02	
24 H		6.42	6.54	6.63	6.70	6.68	
<u>Day 3</u>							
0 H		6.93	6.91	6.74	6.44	6.07	
24 H		6.51	6.57	6.69	6.78	6.71	
<u>Day 4</u>							
0 H		7.25	7.10	7.05	6.68	6.19	
24 H		6.58	6.48	6.55	6.59	6.67	
<u>Day 5</u>							
0 H		6.64	6.65	6.56	6.65	6.36	
24 H		6.68	6.45	6.48	6.57	6.62	
<u>Day 6</u>							
0 H		6.70	6.70	6.57	6.69	6.41	
24 H		7.20	6.86	6.94	7.04	7.10	
<u>Day 7</u>							
24 H		6.34	6.43	6.53	6.61	6.65	

TABLE A27-1. (CONTINUED) - CONDUCTIVITY ( $\mu$ MHOS/CM)

	<u>Test Concentrations (Percent Groundwater by Volume)</u>	
	0	100
<u>Day 0</u>		
0 H	140	1500
<u>Day 1</u>		
0 H	155	1600
<u>Day 2</u>		
0 H	155	
<u>Day 3</u>		
0 H	155	
<u>Day 4</u>		
0 H	155	
<u>Day 5</u>		
0 H	155	
<u>Day 6</u>		
0 H	155	
<u>Day 7</u>		
24 H	152	



TABLE A27-1. (CONTINUED) - ALKALINITY (MG/L AS CaCO<sub>3</sub>)

<u>Test Concentrations (Percent Groundwater by Volume)</u>		
	<u>0</u>	<u>100</u>
<u>Day 0</u>		
0 H	50	<sup>a</sup>
<u>Day 1</u>		
0 H	50	<sup>a</sup>
<u>Day 2</u>		
0 H	50	
<u>Day 3</u>		
0 H	45	
<u>Day 4</u>		
0 H	50	
<u>Day 5</u>		
0 H	50	
<u>Day 6</u>		
0 H	50	
<u>Day 7</u>		
24 H	49	

<sup>a</sup> Could not obtain measurement.

TABLE A27-1. (CONTINUED) - HARDNESS (MG/L AS CaCO<sub>3</sub>)

<u>Test Concentrations (Percent Groundwater by Volume)</u>		
	<u>0</u>	<u>100</u>
<u>Day 0</u>		
0 H	48	a
<u>Day 1</u>		
0 H	54	a
<u>Day 2</u>		
0 H	54	
<u>Day 3</u>		
0 H	54	
<u>Day 4</u>		
0 H	54	
<u>Day 5</u>		
0 H	46	
<u>Day 6</u>		
0 H	46	
<u>Day 7</u>		
24 H	50	

<sup>a</sup> Could not obtain measurement.

TABLE A27-2. FATHEAD MINNOW BEACH POINT RAW GROUNDWATER TOXICITY  
TEST DATA (TEST NO. 1) - SURVIVAL AFTER 96 HOURS OF  
EXPOSURE

Concentration (% Groundwater by Volume)	Rep	Number Tested	No. Alive at 96 Hours	Percent Alive
UMD/WREC Control	A	10	10	100
	B	10	10	100
	C	10	10	100
	D	10	10	100
10	A	10	10	100
	B	10	10	100
	C	10	10	100
	D	10	10	100
18	A	10	10	100
	B	10	10	100
	C	10	10	100
	D	10	10	100
32	A	10	10	100
	B	10	10	100
	C	10	10	100
	D	10	10	100
56	A	10	9	90
	B	10	10	100
	C	10	10	100
	D	10	10	100
100	A	10	0	0
	B	10	0	0
	C	10	0	0
	D	10	0	0

TABLE A27-3. FATHEAD MINNOW BEACH POINT RAW GROUNDWATER TOXICITY  
TEST DATA (TEST NO. 1) - LARVAL SURVIVAL AND DRY  
WEIGHT AFTER 7 DAYS OF EXPOSURE

Conc (% by Vol)	Rep	Number Larvae Alive	Percent Survival	Dry Weight (mg)	Mean Dry Weight (mg)
UMD/WREC Control	1	10	100	0.76	0.69
	2	10	100	0.61	
	3	10	100	0.70	
	4	10	100	0.67	
APG-EA Diluent Water	1	10	100	0.71	0.67
	2	10	100	0.61	
	3	10	100	0.70	
	4	10	100	0.66	
10	1	10	100	0.71	0.68
	2	10	100	0.60	
	3	10	100	0.70	
	4	10	100	0.71	
18	1	10	100	0.65	0.67
	2	10	100	0.71	
	3	10	100	0.56	
	4	10	100	0.75	
32	1	10	100	0.67	0.62
	2	9	90	0.66	
	3	10	100	0.61	
	4	10	100	0.56	
56	1	9	90	0.41	0.40
	2	10	100	0.41	
	3	9	90	0.35	
	4	9	90	0.42	
100	1	0	0		
	2	0	0		
	3	0	0		
	4	0	0		

TABLE A27-4. FATHEAD MINNOW BEACH POINT RAW GROUNDWATER TOXICITY  
TEST STATISTICAL ANALYSIS (TEST NO. 1) - DRY WEIGHT  
OF LARVAE AFTER 7 DAYS OF EXPOSURE

---

Data Transformation:

None

Chi-Square Test for Normality:

Calculated test statistic:	6.40
Alpha value:	0.01
Critical value:	13.28
Conclusion:	Fail to reject the null hypothesis that the data are normally distributed

Bartlett's Test for Homogeneity of Variances:

Calculated test statistic:	2.57
Alpha value:	0.01
Critical value:	15.09
Conclusion:	Fail to reject the null hypothesis that the variances are homogenous

ANOVA:

Calculated test statistic:	16.67
Alpha value:	0.05
Critical value:	2.41
Conclusion:	Reject the null hypothesis that all groups are equal

Dunnett's Test:

Calculated test statistic:	See Table A27-5
Alpha value:	0.05
Critical value:	2.41
Conclusion:	Reject the null hypothesis that all groups are equal

---

TABLE A27-5. FATHEAD MINNOW BEACH POINT RAW GROUNDWATER TOXICITY TEST STATISTICAL ANALYSIS (TEST NO. 1) - RESULTS OF DUNNETT'S TEST ON DRY WEIGHT OF LARVAE AFTER 7 DAYS OF EXPOSURE

Conc (% by Vol)	No. of Reps	Mean Dry Weight (mg)	T Statistic	Significance
UMD/WREC Control	4	0.69		
APG-EA Diluent Water	4	0.67	0.39	
10	4	0.68	0.13	
18	4	0.67	0.45	
32	4	0.63	1.55	
56	4	0.40	7.41	*

\* Significantly different at alpha = 0.05 (Dunnett's critical value = 2.41).

APPENDIX 28

FATHEAD MINNOW ACUTE AND 7-DAY SURVIVAL AND GROWTH  
TEST CONDUCTED ON BEACH POINT BUFFERED (pH  $\approx$ 7)  
GROUNDWATER (WELL CC-33B)  
(TEST NO. 1)

Test Method:	EPA/600/4-89/001 (Weber et al., 1989)
Type of Test:	Static renewal (every 24 h)
Date:	April 7-14, 1993
Investigator:	S.D. Turley
Laboratory:	UMD/WREC
Groundwater:	
Source:	APG-EA Beach Point Well CC-33B
Chemical Characteristics:	See Appendix 48
Dilution Water:	
Source:	20% Perrier: 80% RO water
Chemical Characteristics:	See Table A28-1
Test Organism:	
Scientific Name:	<u>Pimephales promelas</u>
Dry Weight:	0.69 mg (mean weight of controls at end of test)
Age at Start of Test:	<24 h
Source:	UMD/WREC culture
Experimental Chambers:	
Material:	600 mL glass beaker
Test Solution Volume:	400 mL
No. Organisms/Replicate:	10
No. Organisms/Treatment:	40
Loading:	<0.5 g/L
Lighting:	Fluorescent; 60-85 foot candles
Aeration:	Prior to renewals

pH Buffer:	10 N NaOH
Endpoints:	Mortality; growth
Water Quality:	Table A28-1

---

#### Results:

##### Mortality:

###### 96-h Exposure:

The data for the 96-h LC50 were obtained from the 7-d study. The buffered groundwater did not affect larval survival. The data are summarized in Table A28-2.

###### 7-d Exposure:

The survival of fathead minnow larvae was not affected after 7 days of exposure to Beach Point buffered groundwater (Table A28-3).

##### Growth:

A significant ( $\alpha = 0.05$ ) reduction in growth occurred in fathead minnow larvae exposed to 100% buffered groundwater (see Tables A28-3, A28-4, and A28-5). The NOEC and LOEC for the larval fish, based on reduced growth, are as follows:

NOEC = 56% raw groundwater by volume.  
LOEC = 100% raw groundwater by volume.



TABLE A28-1. SUMMARY OF THE BEACH POINT BUFFERED GROUNDWATER  
BIOASSAY TEST WATER QUALITY DATA FOR THE FATHEAD  
MINNOW 7-DAY TEST (TEST NO. 1) - DISSOLVED OXYGEN  
(MG/L)

		<u>Test Concentrations (Percent Groundwater by Volume)</u>			
		0	32	56	100
<u>Day 0</u>					
0 H		8.8	8.1	8.1	8.2
<u>Day 1</u>					
0 H		8.7	8.2	8.2	5.6
24 H		8.1	8.0	8.0	8.1
<u>Day 2</u>					
0 H		8.1	8.2	7.3	6.6
24 H		6.5	6.8	6.8	7.0
<u>Day 3</u>					
0 H		8.5	8.2	8.2	7.5
24 H		6.4	6.7	6.7	6.9
<u>Day 4</u>					
0 H		8.6	7.9	7.9	6.2
24 H		6.3	6.0	6.0	6.7
<u>Day 5</u>					
0 H		8.2	7.5	7.5	5.1
24 H		6.4	6.1	6.1	6.5
<u>Day 6</u>					
0 H		8.0	8.1	8.1	6.1
24 H		6.1	6.0	5.9	6.0
<u>Day 7</u>					
24 H		6.6	6.6	6.6	6.5

TABLE A28-1. (CONTINUED) - pH (STANDARD UNITS)

	<u>Test Concentrations (Percent Groundwater by Volume)</u>			
	0	32	56	100
<u>Day 0</u>				
0 H	6.71	6.47	6.61	6.98
<u>Day 1</u>				
0 H	6.46	6.37	6.51	6.69
24 H	6.63	6.65	6.87	7.06
<u>Day 2</u>				
0 H	7.30	6.91	6.97	7.05
24 H	6.42	6.75	7.02	7.14
<u>Day 3</u>				
0 H	6.93	6.79	6.84	6.92
24 H	6.51	6.86	7.10	7.17
<u>Day 4</u>				
0 H	7.25	6.91	7.00	7.06
24 H	6.58	6.91	7.03	7.00
<u>Day 5</u>				
0 H	6.64	6.89	6.95	7.00
24 H	6.68	6.61	6.69	6.90
<u>Day 6</u>				
0 H	6.70	6.91	6.93	6.95
24 H	7.20	7.14	7.18	7.20
<u>Day 7</u>				
24 H	6.34	6.86	6.95	7.08

TABLE A28-1. (CONTINUED) - CONDUCTIVITY ( $\mu$ MHOS/CM)

<u>Test Concentrations (Percent Groundwater by Volume)</u>		
	<u>0</u>	<u>100</u>
<u>Day 0</u>		
0 H	140	1700
<u>Day 1</u>		
0 H	155	1700
<u>Day 2</u>		
0 H	155	1700
<u>Day 3</u>		
0 H	155	1700
<u>Day 4</u>		
0 H	155	1750
<u>Day 5</u>		
0 H	155	1800
<u>Day 6</u>		
0 H	155	1800
<u>Day 7</u>		
24 H	152	1736

TABLE A28-1. (CONTINUED) - ALKALINITY (MG/L AS CaCO<sub>3</sub>)

	<u>Test Concentrations (Percent Groundwater by Volume)</u>	
	<u>0</u>	<u>100</u>
<u>Day 0</u>		
0 H	50	80
<u>Day 1</u>		
0 H	50	80
<u>Day 2</u>		
0 H	50	85
<u>Day 3</u>		
0 H	45	80
<u>Day 4</u>		
0 H	50	100
<u>Day 5</u>		
0 H	50	85
<u>Day 6</u>		
0 H	50	85
<u>Day 7</u>		
24 H	49	85

TABLE A28-1. (CONTINUED) - HARDNESS (MG/L AS  $\text{CaCO}_3$ )

<u>Test Concentrations (Percent Groundwater by Volume)</u>		
	<u>0</u>	<u>100</u>
<u>Day 0</u>		
0 H	48	280
<u>Day 1</u>		
0 H	54	170
<u>Day 2</u>		
0 H	54	136
<u>Day 3</u>		
0 H	54	148
<u>Day 4</u>		
0 H	54	138
<u>Day 5</u>		
0 H	46	160
<u>Day 6</u>		
0 H	46	160
<u>Day 7</u>		
24 H	50	170

TABLE A28-2. FATHEAD MINNOW BEACH POINT BUFFERED GROUNDWATER TOXICITY TEST DATA (TEST NO. 1) - SURVIVAL AFTER 96 HOURS OF EXPOSURE

Concentration (% Groundwater by Volume)	Rep	Number Tested	No. Alive at 96 Hours	Percent Alive
UMD/WREC Control	A	10	10	100
	B	10	10	100
	C	10	10	100
	D	10	10	100
10	A	<sup>a</sup>		
	B	<sup>a</sup>		
	C	<sup>a</sup>		
	D	<sup>a</sup>		
18	A	<sup>a</sup>		
	B	<sup>a</sup>		
	C	<sup>a</sup>		
	D	<sup>a</sup>		
32	A	10	10	100
	B	10	10	100
	C	10	10	100
	D	10	10	100
56	A	10	9	90
	B	10	10	100
	C	10	10	100
	D	10	10	100
100	A	10	10	100
	B	10	10	100
	C	10	10	100
	D	10	10	100

<sup>a</sup> Larvae were not tested at this treatment.

TABLE A28-3. FATHEAD MINNOW BEACH POINT BUFFERED GROUNDWATER  
TOXICITY TEST DATA (TEST NO. 1) - LARVAL SURVIVAL  
AND DRY WEIGHT AFTER 7 DAYS OF EXPOSURE

Conc (% by Vol)	Rep	Number Larvae Alive	Percent Survival	Dry Weight (mg)	Mean Dry Weight (mg)
UMD/WREC Control	1	10	100	0.76	0.69
	2	10	100	0.61	
	3	10	100	0.70	
	4	10	100	0.67	
32	1	10	100	0.68	0.65
	2	10	100	0.62	
	3	10	100	0.61	
	4	10	100	0.68	
56	1	10	100	0.76	0.67
	2	10	100	0.70	
	3	10	100	0.62	
	4	10	100	0.59	
100	1	10	100	0.50	0.54
	2	10	100	0.55	
	3	10	100	0.57	
	4	10	100	0.52	

TABLE A28-4. FATHEAD MINNOW BEACH POINT BUFFERED GROUNDWATER  
TOXICITY TEST STATISTICAL ANALYSIS (TEST NO. 1) -  
DRY WEIGHT OF LARVAE AFTER 7 DAYS OF EXPOSURE

---

Data Transformation:

None

Chi-Square Test for Normality:

Calculated test statistic:	3.84
Alpha value:	0.01
Critical value:	13.28
Conclusion:	Fail to reject the null hypothesis that the data are normally distributed

Bartlett's Test for Homogeneity of Variances:

Calculated test statistic:	2.75
Alpha value:	0.01
Critical value:	11.34
Conclusion:	Fail to reject the null hypothesis that the variances are homogenous

ANOVA:

Calculated test statistic:	6.00
Alpha value:	0.05
Critical Value:	3.49
Conclusion:	Reject the null hypothesis that all groups are equal

Dunnett's Test:

Calculated test statistic:	See Table A28-5
Alpha value:	0.05
Critical value:	2.29
Conclusion:	Reject the null hypothesis that all groups are equal

---



TABLE A28-5. FATHEAD MINNOW BEACH POINT BUFFERED GROUNDWATER TOXICITY TEST STATISTICAL ANALYSIS (TEST NO. 1) - RESULTS OF DUNNETT'S TEST ON DRY WEIGHT OF LARVAE AFTER 7 DAYS OF EXPOSURE

Conc (% by Vol)	No. of Reps	Mean Dry Weight (mg)	T Statistic	Significance
UMD/WREC Control	4	0.69		
32	4	0.65	0.994	
56	4	0.67	0.458	
100	4	0.54	3.873	*

\* Significantly different at  $\alpha = 0.05$  (Dunnett's critical value = 2.29).

## APPENDIX 29

### FATHEAD MINNOW ACUTE AND 7-DAY SURVIVAL AND GROWTH TEST CONDUCTED ON BEACH POINT RAW (pH $\approx$ 4) GROUNDWATER (WELL CC-33B) (TEST NO. 2)

Test Method:	EPA/600/4-89/001 (Weber et al., 1989)
Type of Test:	Static renewal (every 24 h)
Date:	June 2-9, 1993
Investigator:	S.D. Turley
Laboratory:	UMD/WREC
Groundwater:	
Source:	APG-EA Beach Point Well CC-33B
Chemical Characteristics:	See Appendix 48
Dilution Water:	
Source:	20% Perrier: 80% RO water
Chemical Characteristics:	See Table A29-1
Test Organism:	
Scientific Name:	<u>Pimephales promelas</u>
Dry Weight:	0.55 mg (mean weight of controls at end of test)
Age at Start of Test:	<24 h
Source:	Chesapeake Cultures Hayes, VA
Experimental Chambers:	
Material:	600 mL glass beaker
Test Solution Volume:	400 mL
No. Organisms/Replicate:	10
No. Organisms/Treatment:	40
Loading:	<0.5 g/L
Lighting:	Fluorescent; 60-85 foot candles

Aeration:	Prior to each renewal
Endpoints:	Mortality; growth
Water Quality:	Table A29-1

---

## Results:

### Mortality:

#### 96-h Exposure:

The data for the 96-h LC50 were obtained from the 7-d study. All organisms exposed to the 100% and 56% raw groundwater by volume treatment died during the 96-h exposure (Table A29-2). All but two larvae died at the next dilution of 32% groundwater by volume. No organisms died in the remaining treatments. The 96-h LC50, which was determined by the moving average angle method, is as follows:

96-h LC50 = 21.6% raw groundwater by volume (95% confidence limits = 19.27-24.01).

#### 7-d Exposure:

Significant ( $\alpha = 0.05$ ) mortality occurred in fathead minnow larvae exposed to 32, 56, and 100% raw groundwater for 7 d (see Tables A29-3, A29-4, and A29-5). The 7-d LC50, which was determined by the moving average angle method, is as follows:

7-d LC50 = 21.6% raw groundwater by volume (95% confidence limits = 19.27-24.01).

### Growth:

A significant ( $\alpha = 0.05$ ) reduction in growth occurred in fathead minnow larvae exposed for 7 d to 18% raw groundwater by volume (see Tables A29-3, A29-6, and A29-7). The NOEC and LOEC for the larval fish, based on reduced growth, are as follows:

NOEC = 10% raw groundwater by volume.

LOEC = 18% raw groundwater by volume.

TABLE A29-1. SUMMARY OF THE BEACH POINT RAW GROUNDWATER BIOASSAY  
TEST WATER QUALITY DATA FOR THE FATHEAD MINNOW 7-  
DAY TEST (TEST NO. 2) - DISSOLVED OXYGEN (MG/L)

	<u>Test Concentrations (Percent Groundwater by Volume)</u>					
	0	10	18	32	56	100
<u>Day 0</u>						
0 H	8.3	8.1	8.1	8.0	7.9	6.6
<u>Day 1</u>						
0 H	8.0	8.0	7.7	7.4	7.5	7.1
24 H	7.2	7.2	7.4	7.5	7.6	7.7
<u>Day 2</u>						
0 H	8.3	8.0	7.9	7.6	7.4	
24 H	7.1	7.3	7.5	7.8		
<u>Day 3</u>						
0 H	8.1	8.0	7.9	7.9		
24 H	7.0	6.8	6.7	6.8		
<u>Day 4</u>						
0 H	8.4	8.2	8.2	8.2		
24 H	6.7	6.7	6.7	6.7		
<u>Day 5</u>						
0 H	8.2	8.1	8.1	8.0		
24 H	7.3	7.5	7.3	7.3		
<u>Day 6</u>						
0 H	7.8	7.8	7.7	8.0		
24 H	7.2	7.3	7.1	7.2		
<u>Day 7</u>						
24 H	7.3	7.2	7.3	7.0		

TABLE A29-1. (CONTINUED) - pH (STANDARD UNITS)

	<u>Test Concentrations (Percent Groundwater by Volume)</u>					
	0	10	18	32	56	100
<u>Day 0</u>						
0 H	6.32	6.31	6.34	6.36	6.31	3.97
<u>Day 1</u>						
0 H	6.50	6.75	6.76	6.74	6.57	3.93
24 H	6.83	6.88	6.95	6.98	6.98	4.68
<u>Day 2</u>						
0 H	6.92	6.99	6.95	6.89	6.58	
24 H	6.76	6.79	6.85	6.89		
<u>Day 3</u>						
0 H	7.02	6.99	6.92	6.86		
24 H	6.82	6.87	6.87	6.94		
<u>Day 4</u>						
0 H	6.90	6.96	6.92	6.84		
24 H	6.90	6.81	6.86	6.82		
<u>Day 5</u>						
0 H	6.38	6.50	6.46	6.41		
24 H	6.56	6.68	6.77	6.81		
<u>Day 6</u>						
0 H	7.25	7.29	7.18	6.79		
24 H	6.68	6.72	6.80	6.88		
<u>Day 7</u>						
24 H	6.71	6.75	6.75	6.77		

TABLE A29-1. (CONTINUED) - CONDUCTIVITY ( $\mu$ MHOS/CM)

<u>Test Concentrations (Percent Groundwater by Volume)</u>		
	<u>0</u>	<u>100</u>
<u>Day 0</u>		
0 H	150	1350
<u>Day 1</u>		
0 H	150	1600
<u>Day 2</u>		
0 H	185	
<u>Day 3</u>		
0 H	140	
<u>Day 4</u>		
0 H	140	
<u>Day 5</u>		
0 H	130	
<u>Day 6</u>		
0 H	140	
<u>Day 7</u>		
24 H	155	

TABLE A29-1. (CONTINUED) - ALKALINITY (MG/L AS CaCO<sub>3</sub>)

<u>Test Concentrations (Percent Groundwater by Volume)</u>		
	<u>0</u>	<u>100</u>
<u>Day 0</u>		
0 H	55	<sup>a</sup>
<u>Day 1</u>		
0 H	55	<sup>a</sup>
<u>Day 2</u>		
0 H	55	
<u>Day 3</u>		
0 H	55	
<u>Day 4</u>		
0 H	55	
<u>Day 5</u>		
0 H	50	
<u>Day 6</u>		
0 H	50	
<u>Day 7</u>		
24 H	50	

<sup>a</sup> Could not obtain measurement.

TABLE A29-1. (CONTINUED) - HARDNESS (MG/L AS CaCO<sub>3</sub>)

<u>Test Concentrations (Percent Groundwater by Volume)</u>		
	<u>0</u>	<u>100</u>
<u>Day 0</u>		
0 H	50	a
<u>Day 1</u>		
0 H	54	a
<u>Day 2</u>		
0 H	60	
<u>Day 3</u>		
0 H	44	
<u>Day 4</u>		
0 H	54	
<u>Day 5</u>		
0 H	40	
<u>Day 6</u>		
0 H	44	
<u>Day 7</u>		
24 H	46	

<sup>a</sup> Could not obtain measurement.



TABLE A29-2. FATHEAD MINNOW BEACH POINT RAW GROUNDWATER TOXICITY  
TEST DATA (TEST NO. 2) - SURVIVAL AFTER 96 HOURS OF  
EXPOSURE

Concentration (% Groundwater by Volume)	Rep	Number Tested	No. Alive at 96 Hours	Percent Alive
UMD/WREC Control	A	10	10	100
	B	10	10	100
	C	10	10	100
	D	10	10	100
10	A	10	10	100
	B	10	10	100
	C	10	9	90
	D	10	10	100
18	A	10	10	100
	B	10	8	80
	C	10	8	80
	D	10	8	80
32	A	10	1	10
	B	10	0	0
	C	10	1	10
	D	10	0	0
56	A	10	0	0
	B	10	0	0
	C	10	0	0
	D	10	0	0
100	A	10	0	0
	B	10	0	0
	C	10	0	0
	D	10	0	0

TABLE A29-3. FATHEAD MINNOW BEACH POINT RAW GROUNDWATER TOXICITY  
TEST DATA (TEST NO. 2) - LARVAL SURVIVAL AND DRY  
WEIGHT AFTER 7 DAYS OF EXPOSURE

Conc (% by Vol)	Rep	Number Larvae Alive	Percent Survival	Dry Weight (mg)	Mean Dry Weight (mg)
UMD/WREC Control	1	10	100	0.56	0.55
	2	10	100	0.53	
	3	10	100	0.55	
	4	10	100	0.57	
APG-EA Diluent Water	1	10	100	0.57	0.59
	2	10	100	0.58	
	3	10	100	0.61	
	4	10	100	0.58	
10	1	10	100	0.50	0.52
	2	10	100	0.53	
	3	9	90	0.52	
	4	10	100	0.52	
18	1	10	100	0.44	0.42
	2	8	80	0.45	
	3	8	80	0.42	
	4	8	80	0.37	
32	1	0	0	0.11	
	2	0	0		
	3	1	10		
	4	0	0		
56	1	0	0		
	2	0	0		
	3	0	0		
	4	0	0		
100	1	0	0		
	2	0	0		
	3	0	0		
	4	0	0		

TABLE A29-4. FATHEAD MINNOW BEACH POINT RAW GROUNDWATER TOXICITY  
TEST STATISTICAL ANALYSIS (TEST NO. 2) - LARVAL  
SURVIVAL AFTER 7 DAYS OF EXPOSURE<sup>a</sup>

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Data Transformation:

Arc sine square root

Chi-Square Test for Normality:

Calculated test statistic:	18.86
Alpha value:	0.01
Critical value:	13.28
Conclusion:	Reject the null hypothesis that the data are normally distributed

Steel's Many-One Rank Test:

Calculated test statistic:	See Table A29-5
Alpha value:	0.05
Critical Value:	10.0
Conclusion:	Reject the null hypothesis that all groups are equal

---

<sup>a</sup> The 56% and 100% raw Beach Point groundwater treatments were not included in the statistical analyses because all organisms died during the test.

TABLE A29-5. FATHEAD MINNOW BEACH POINT RAW GROUNDWATER TOXICITY TEST STATISTICAL ANALYSIS (TEST NO. 2) - RESULTS OF STEEL'S MANY-ONE RANK TEST ON LARVAL SURVIVAL AFTER 7 DAYS OF EXPOSURE

Conc (% by Vol)	No. of Reps	Mean Survival (%) <sup>a</sup>	Rank Sum	Significance
UMD/WREC Control	4	100		
APG-EA Diluent Water	4	100	18.0	
10	4	97.5	16.0	
18	4	85.0	12.0	
32	4	2.5	10.0	*

<sup>a</sup> Values given are actual percent survival means rather than arc sine square root transformed means which were used in the statistical analysis.

\* Significantly different at alpha = 0.05 (Steel's critical value = 10.0).

TABLE A29-6. FATHEAD MINNOW BEACH POINT RAW GROUNDWATER TOXICITY  
TEST STATISTICAL ANALYSIS (TEST NO. 2) - DRY WEIGHT  
OF LARVAE AFTER 7 DAYS OF EXPOSURE<sup>a</sup>

---

Data Transformation:

None

Chi-Square Test for Normality:

Calculated test statistic:	2.61
Alpha value:	0.01
Critical value:	13.28
Conclusion:	Fail to reject the null hypothesis that the data are normally distributed

Bartlett's Test for Homogeneity of Variances:

Calculated test statistic:	3.43
Alpha value:	0.01
Critical value:	11.34
Conclusion:	Fail to reject the null hypothesis that the variances are homogenous

ANOVA:

Calculated test statistic:	40.80
Alpha value:	0.05
Critical value:	3.49
Conclusion:	Reject the null hypothesis that all groups are equal

Dunnett's Test:

Calculated test statistic:	See Table A29-7
Alpha value:	0.05
Critical value:	2.29
Conclusion:	Reject the null hypothesis that all groups are equal

---

<sup>a</sup> The 32% buffered Beach Point groundwater treatment was not included in the statistical analyses because all concentrations above the NOEC for survival are excluded from the hypothesis test for growth effects.

TABLE A29-7. FATHEAD MINNOW BEACH POINT RAW GROUNDWATER TOXICITY TEST STATISTICAL ANALYSIS (TEST NO. 2) - RESULTS OF DUNNETT'S TEST ON DRY WEIGHT OF LARVAE AFTER 7 DAYS OF EXPOSURE

Conc (% by Vol)	No. of Reps	Mean Dry Weight (mg)	T Statistic	Significance
UMD/WREC Control	4	0.55		
APG-EA Diluent Water	4	0.59	-2.06	
10	4	0.52	2.21	
18	4	0.42	8.38	*

\* Significantly different at alpha = 0.05 (Dunnett's critical value = 2.29).

APPENDIX 30

FATHEAD MINNOW ACUTE AND 7-DAY SURVIVAL AND GROWTH  
TEST CONDUCTED ON BEACH POINT BUFFERED (pH  $\approx$ 7)  
GROUNDWATER (WELL CC-33B)  
(TEST NO. 2)

Test Method: EPA/600/4-89/001  
(Weber et al., 1989)

Type of Test: Static renewal (every 24 h)

Date: June 2-9, 1993

Investigator: S.D. Turley

Laboratory: UMD/WREC

Groundwater:

Source: APG-EA Beach Point Well CC-33B  
Chemical Characteristics: See Appendix 48

Dilution Water:

Source: 20% Perrier: 80% RO water  
Chemical Characteristics: See Table A30-1

Test Organism:

Scientific Name: Pimephales promelas  
Dry Weight: 0.55 mg (mean weight of  
controls at end of test)

Age at Start of Test: <24 h  
Source: Chesapeake Cultures  
Hayes, VA

Experimental Chambers:

Material: 600 mL glass beaker  
Test Solution Volume: 400 mL

No. Organisms/Replicate: 10

No. Organisms/Treatment: 40

Loading: <0.5 g/L

Lighting: Fluorescent; 60-85 foot  
candles

Aeration:	Prior to renewals
pH Buffer:	10 N NaOH
Endpoints:	Mortality; growth
Water Quality:	Table A30-1

---

#### Results:

##### Mortality:

###### 96-h Exposure:

The data for the 96-h LC50 were obtained from the 7-d study. Fifteen percent of the larvae exposed to 100% buffered groundwater died during the 96-h exposure; thus, a LC50 could not be calculated. The data are summarized in Table A30-2.

###### 7-d Exposure:

Significant ( $\alpha = 0.05$ ) mortality occurred in fathead minnow larvae exposed to 100% raw groundwater for 7 d (see Tables A30-3, A30-4, and A30-5). However, less than 50% mortality occurred to the fathead minnow exposed for 7 days to 100% Beach Point buffered groundwater; thus, an LC50 could not be calculated (Table A30-3). The NOEC and LOEC for the larval fish, based on mortality are as follows:

NOEC = 56% raw groundwater by volume.  
LOEC = 100% raw groundwater by volume.

##### Growth:

Growth (dry weight) of the fathead minnow larvae was not affected by 7 days of exposure to buffered groundwater (see Tables A30-3, and A30-6).



TABLE A30-1. SUMMARY OF THE BEACH POINT BUFFERED GROUNDWATER  
BIOASSAY TEST WATER QUALITY DATA FOR THE FATHEAD  
MINNOW 7-DAY TEST (TEST NO. 21) - DISSOLVED OXYGEN  
(MG/L)

		<u>Test Concentrations (Percent Groundwater by Volume)</u>			
		0	32	56	100
<u>Day 0</u>					
0 H	8.3	7.8	7.6	6.5	
<u>Day 1</u>					
0 H	8.0	7.3	6.6	6.2	
24 H	7.2	7.1	7.1	7.1	
<u>Day 2</u>					
0 H	8.3	8.0	8.0	6.2	
24 H	7.1	7.2	7.3	7.3	
<u>Day 3</u>					
0 H	8.1	7.6	7.5	7.5	
24 H	7.0	7.3	7.2	7.2	
<u>Day 4</u>					
0 H	8.4	8.1	8.1	8.0	
24 H	6.7	7.2	7.1	7.2	
<u>Day 5</u>					
0 H	8.2	7.9	7.9	8.0	
24 H	7.3	7.0	7.0	7.1	
<u>Day 6</u>					
0 H	7.8	7.8	7.8	7.6	
24 H	7.2	7.0	7.1	7.0	
<u>Day 7</u>					
24 H	7.3	7.1	7.0	7.0	

TABLE A30-1. (CONTINUED) - pH (STANDARD UNITS)

	<u>Test Concentrations (Percent Groundwater by Volume)</u>			
	0	32	56	100
<u>Day 0</u>				
0 H	6.32	6.75	6.92	6.96
<u>Day 1</u>				
0 H	6.50	6.94	7.06	7.13
24 H	6.83	6.64	6.89	6.95
<u>Day 2</u>				
0 H	6.92	7.08	7.34	7.60
24 H	6.76	6.91	7.09	7.29
<u>Day 3</u>				
0 H	7.07	7.13	7.23	7.32
24 H	6.82	7.04	7.20	7.41
<u>Day 4</u>				
0 H	6.90	6.84	6.96	7.18
24 H	6.90	7.03	7.19	7.38
<u>Day 5</u>				
0 H	6.38	7.26	7.33	7.57
24 H	6.56	6.99	7.11	7.25
<u>Day 6</u>				
0 H	7.25	7.07	7.17	7.23
24 H	6.68	7.03	7.17	7.39
<u>Day 7</u>				
24 H	6.71	7.05	7.13	7.26

TABLE A30-1. (CONTINUED) - CONDUCTIVITY ( $\mu$ MHOS/CM)

<u>Test Concentrations (Percent Groundwater by Volume)</u>		
	<u>0</u>	<u>100</u>
<u>Day 0</u>		
0 H	150	1400
<u>Day 1</u>		
0 H	150	1600
<u>Day 2</u>		
0 H	185	1500
<u>Day 3</u>		
0 H	140	1700
<u>Day 4</u>		
0 H	140	1350
<u>Day 5</u>		
0 H	130	1700
<u>Day 6</u>		
0 H	140	1550
<u>Day 7</u>		
24 H	150	1650

TABLE A30-1. (CONTINUED) - ALKALINITY (MG/L AS CaCO<sub>3</sub>)

	<u>Test Concentrations (Percent Groundwater by Volume)</u>	
	<u>0</u>	<u>100</u>
<u>Day 0</u>		
0 H	55	100
<u>Day 1</u>		
0 H	55	120
<u>Day 2</u>		
0 H	55	110
<u>Day 3</u>		
0 H	55	125
<u>Day 4</u>		
0 H	55	125
<u>Day 5</u>		
0 H	50	125
<u>Day 6</u>		
0 H	50	100
<u>Day 7</u>		
24 H	50	110

TABLE A30-1. (CONTINUED) - HARDNESS (MG/L AS CaCO<sub>3</sub>)

<u>Test Concentrations (Percent Groundwater by Volume)</u>		
	<u>0</u>	<u>100</u>
<u>Day 0</u>		
0 H	50	170
<u>Day 1</u>		
0 H	54	128
<u>Day 2</u>		
0 H	60	148
<u>Day 3</u>		
0 H	44	134
<u>Day 4</u>		
0 H	54	154
<u>Day 5</u>		
0 H	40	170
<u>Day 6</u>		
0 H	44	164
<u>Day 7</u>		
24 H	50	140

TABLE A30-2. FATHEAD MINNOW BEACH POINT BUFFERED GROUNDWATER  
TOXICITY TEST DATA (TEST NO. 2) - SURVIVAL AFTER 96  
HOURS OF EXPOSURE

Concentration (% Groundwater by Volume)	Rep	Number Tested	No. Alive at 96 Hours	Percent Alive
UMD/WREC Control	A	10	10	100
	B	10	10	100
	C	10	10	100
	D	10	10	100
10	A	a		
	B	a		
	C	a		
	D	a		
18	A	a		
	B	a		
	C	a		
	D	a		
32	A	10	9	90
	B	10	10	100
	C	10	9	90
	D	10	9	90
56	A	10	10	100
	B	10	10	100
	C	10	10	100
	D	10	10	100
100	A	10	7	70
	B	10	9	90
	C	10	9	90
	D	10	9	90

<sup>a</sup> Larvae were not tested at this treatment.

TABLE A30-3. FATHEAD MINNOW BEACH POINT BUFFERED GROUNDWATER  
TOXICITY TEST DATA (TEST NO. 2) - LARVAL SURVIVAL  
AND DRY WEIGHT AFTER 7 DAYS OF EXPOSURE

Conc (% by Vol)	Rep	Number Larvae Alive	Percent Survival	Dry Weight (mg)	Mean Dry Weight (mg)
UMD/WREC Control	1	10	100	0.56	0.55
	2	10	100	0.53	
	3	10	100	0.55	
	4	10	100	0.57	
32	1	9	90	0.54	0.53
	2	9	90	0.55	
	3	10	100	0.53	
	4	8	80	0.50	
56	1	9	90	0.48	0.53
	2	9	90	0.55	
	3	10	100	0.51	
	4	10	100	0.57	
100	1	6	60	0.54	0.50
	2	9	90	0.48	
	3	8	80	0.48	
	4	9	90	0.51	

TABLE A30-4. FATHEAD MINNOW BEACH POINT BUFFERED GROUNDWATER  
TOXICITY TEST STATISTICAL ANALYSIS (TEST NO. 2) -  
LARVAL SURVIVAL AFTER 7 DAYS OF EXPOSURE

---

Data Transformation:

Arc sine square root

Chi-Square Test for Normality:

Calculated test statistic:	2.61
Alpha value:	0.01
Critical value:	13.28
Conclusion:	Fail to reject the null hypothesis that the data are normally distributed

Bartlett's Test for Homogeneity of Variances:

Data failed to meet homogeneity of variance test because at least one group had zero variance.

Steel' Many One Rank Test:

Calculated test statistic:	See Table A30-5
Alpha value:	0.05
Critical Value:	10.0
Conclusion:	Reject the null hypothesis that all groups are equal

---



TABLE A30-5. FATHEAD MINNOW BEACH POINT BUFFERED GROUNDWATER TOXICITY TEST STATISTICAL ANALYSIS (TEST NO. 2) - RESULTS OF STEEL' MANY ONE RANK TEST ON LARVAL SURVIVAL AFTER 7 DAYS OF EXPOSURE

Conc (% by Vol)	No. of Reps	Mean Survival (%) <sup>a</sup>	Rank Sum	Significance
UMD/WREC Control	4	100		
32	4	90	12.0	
56	4	95	14.0	
100	4	80	10.0	*

<sup>a</sup> Values given are actual percent survival means rather than arc sine square root transformed means which were used in the statistical analysis.

\* Significantly different at alpha = 0.05 (Steel's critical value = 10.0).

TABLE A30-5. FATHEAD MINNOW BEACH POINT BUFFERED GROUNDWATER TOXICITY TEST STATISTICAL ANALYSIS (TEST NO. 2) - DRY WEIGHT OF LARVAE AFTER 7 DAYS OF EXPOSURE<sup>a</sup>

---

Data Transformation:

None

Chi-Square Test for Normality:

Calculated test statistic:	2.06
Alpha value:	0.01
Critical value:	13.28
Conclusion:	Fail to reject the null hypothesis that the data are normally distributed

Bartlett's Test for Homogeneity of Variances:

Calculated test statistic:	2.14
Alpha value:	0.01
Critical value:	9.21
Conclusion:	Fail to reject the null hypothesis that the variances are homogenous

ANOVA:

Calculated test statistic:	1.00
Alpha value:	0.05
Critical Value:	4.26
Conclusion:	Reject the null hypothesis that all groups are equal

---

<sup>a</sup> The 100% buffered Beach Point groundwater treatment was not included in the statistical analyses because all concentrations above the NOEC for survival are excluded from the hypothesis test for growth effects.

APPENDIX 31

FATHEAD MINNOW ACUTE AND 7-DAY SURVIVAL AND GROWTH  
TEST CONDUCTED ON BEACH POINT RAW (pH  $\approx$ 4)  
GROUNDWATER (WELL CC-33B)  
(TEST NO. 3)

Test Method:	EPA/600/4-89/001 (Weber et al., 1989)
Type of Test:	Static renewal (every 24 h)
Date:	August 24-31, 1993
Investigator:	S.D. Turley
Laboratory:	UMD/WREC
Groundwater:	
Source:	APG-EA Beach Point Well CC-33B
Chemical Characteristics:	See Appendix 48
Dilution Water:	
Source:	20% Perrier: 80% RO water
Chemical Characteristics:	See Table A31-1
Test Organism:	
Scientific Name:	<u>Pimephales promelas</u>
Dry Weight:	0.58 mg (mean weight of controls at end of test)
Age at Start of Test:	<24 h
Source:	UMD/WREC culture
Experimental Chambers:	
Material:	600 mL glass beaker
Test Solution Volume:	400 mL
No. Organisms/Replicate:	10
No. Organisms/Treatment:	40
Loading:	<0.5 g/L
Lighting:	Fluorescent; 60-85 foot candles

Aeration:	Prior to each renewal
Endpoints:	Mortality; growth
Water Quality:	Table A31-1

---

## Results:

### Mortality:

#### 96-h Exposure:

The data for the 96-h LC50 were obtained from the 7-d study. All organisms exposed to the 100% raw groundwater and 87.5% of the larvae in the 56% raw groundwater by volume treatment died during the 96-h exposure (Table A31-2). The 96-h LC50, which was determined by the moving average angle method, is as follows:

96-h LC50 = 44.8% raw groundwater by volume (95% confidence limits = 40.63-49.49).

#### 7-d Exposure:

Significant ( $\alpha = 0.05$ ) mortality occurred in fathead minnow larvae exposed to 100% and 56% groundwater by volume for 7 d (see Tables A31-3, A31-4, and A31-5). The 7-d LC50, which was determined by the moving average angle method, is as follows:

7-d LC50 = 38.7% raw groundwater by volume (95% confidence limits = 34.22-43.55).

The NOEC and LOEC for the larval fish, based on mortality, are as follows:

NOEC = 32% raw groundwater by volume.

LOEC = 56% raw groundwater by volume.

### Growth:

The growth of fathead minnow larvae was not affected by a 7-d exposure to concentrations which ranged from 10% to 32% groundwater by volume (see Tables A31-3 and A31-6).

TABLE A31-1. SUMMARY OF THE BEACH POINT RAW GROUNDWATER BIOASSAY  
TEST WATER QUALITY DATA FOR THE FATHEAD MINNOW 7-  
DAY TEST (TEST NO. 3) - DISSOLVED OXYGEN (MG/L)

		<u>Test Concentrations (Percent Groundwater by Volume)</u>					
		0	10	18	32	56	100
<u>Day 0</u>							
0 H		8.0	7.7	7.7	7.5	6.9	6.3
<u>Day 1</u>							
0 H		8.3	7.9	7.7	7.5	6.7	
24 H		5.5	5.1	5.8	5.9	6.0	7.0
<u>Day 2</u>							
0 H		8.1	8.0	7.9	7.5	7.2	
24 H		6.0	6.5	6.0	6.5	6.5	
<u>Day 3</u>							
0 H		8.2	8.0	7.8	7.4	7.0	
24 H		6.0	6.3	6.4	6.6	6.8	
<u>Day 4</u>							
0 H		8.1	8.0	7.7	7.5	7.3	
24 H		6.0	6.2	5.8	6.0	6.1	
<u>Day 5</u>							
0 H		8.3	8.1	7.9	7.7	7.5	
24 H		6.2	6.1	5.9	6.3	5.9	
<u>Day 6</u>							
0 H		8.4	8.2	8.1	7.9	7.1	
24 H		6.1	6.0	6.0	6.2	5.9	
<u>Day 7</u>							
24 H		6.3	6.1	6.0	6.1	6.0	

TABLE A31-1. (CONTINUED) - pH (STANDARD UNITS)

	<u>Test Concentrations (Percent Groundwater by Volume)</u>					
	0	10	18	32	56	100
<u>Day 0</u>						
0 H	7.99	7.57	7.21	6.64	6.03	3.97
<u>Day 1</u>						
0 H	7.30	6.95	6.65	6.31	5.64	
24 H	7.09	7.02	6.96	6.89	6.66	4.45
<u>Day 2</u>						
0 H	8.06	7.39	6.99	6.52	5.94	
24 H	7.53	7.08	6.87	6.73	6.47	
<u>Day 3</u>						
0 H	7.75	7.41	7.16	6.73	6.01	
24 H	7.09	7.00	6.90	6.76	6.33	
<u>Day 4</u>						
0 H	7.80	7.44	7.17	6.84	6.09	
24 H	7.08	7.02	7.00	6.93	6.60	
<u>Day 5</u>						
0 H	7.57	7.37	7.07	6.80	6.01	
24 H	7.15	7.00	7.10	6.87	6.51	
<u>Day 6</u>						
0 H	7.83	7.20	6.81	6.41	5.89	
24 H	7.29	7.11	7.15	6.99	6.60	
<u>Day 7</u>						
24 H	7.22	7.13	7.02	6.89	6.49	

TABLE A31-1. (CONTINUED) - CONDUCTIVITY ( $\mu$ MHOS/CM)

<u>Test Concentrations (Percent Groundwater by Volume)</u>			
	<u>0</u>	<u>56</u>	<u>100</u>
<u>Day 0</u>			
0 H	170	1130	1400
<u>Day 1</u>			
0 H	160	1100	
<u>Day 2</u>			
0 H	160	1100	
<u>Day 3</u>			
0 H	160	1050	
<u>Day 4</u>			
0 H	160	1000	
<u>Day 5</u>			
0 H	170	1050	
<u>Day 6</u>			
0 H	160	1100	
<u>Day 7</u>			
24 H	150	1150	

TABLE A31-1. (CONTINUED) - ALKALINITY (MG/L AS CaCO<sub>3</sub>)

	<u>Test Concentrations (Percent Groundwater by Volume)</u>		
	0	56	100
<u>Day 0</u>			
0 H	50	25	a
<u>Day 1</u>			
0 H	55	30	a
<u>Day 2</u>			
0 H	55	20	a
<u>Day 3</u>			
0 H	50	25	
<u>Day 4</u>			
0 H	55	30	
<u>Day 5</u>			
0 H	50	25	
<u>Day 6</u>			
0 H	55	20	
<u>Day 7</u>			
24 H	55	25	

<sup>a</sup> Could not obtain measurement.



TABLE A31-1. (CONTINUED) - HARDNESS (MG/L AS CaCO<sub>3</sub>)

		<u>Test Concentrations (Percent Groundwater by Volume)</u>		
		0	56	100
<u>Day 0</u>				
0 H	52		a	a
<u>Day 1</u>				
0 H	50		a	
<u>Day 2</u>				
0 H	52		a	
<u>Day 3</u>				
0 H	52		a	
<u>Day 4</u>				
0 H	50		a	
<u>Day 5</u>				
0 H	54		a	
<u>Day 6</u>				
0 H	50		a	
<u>Day 7</u>				
24 H	54		a	

<sup>a</sup> Could not obtain measurement.

TABLE A31-2. FATHEAD MINNOW BEACH POINT RAW GROUNDWATER TOXICITY  
TEST DATA (TEST NO. 3) - SURVIVAL AFTER 96 HOURS OF  
EXPOSURE

Concentration (% Groundwater by Volume)	Rep	Number Tested	No. Alive at 96 Hours	Percent Alive
UMD/WREC Control	A	10	10	100
	B	10	10	100
	C	10	10	100
	D	10	10	100
10	A	10	10	100
	B	10	10	100
	C	10	9	90
	D	10	10	100
18	A	10	9	90
	B	10	9	90
	C	10	10	100
	D	10	9	90
32	A	10	9	90
	B	10	9	90
	C	10	10	100
	D	10	10	100
56	A	10	0	0
	B	10	0	0
	C	10	3	30
	D	10	2	20
100	A	10	0	0
	B	10	0	0
	C	10	0	0
	D	10	0	0

TABLE A31-4. FATHEAD MINNOW BEACH POINT RAW GROUNDWATER TOXICITY  
TEST DATA (TEST NO. 3) - LARVAL SURVIVAL AND DRY  
WEIGHT AFTER 7 DAYS OF EXPOSURE

Conc (% by Vol)	Rep	Number Larvae Alive	Percent Survival	Dry Weight (mg)	Mean Dry Weight (mg)
UMD/WREC Control	1	10	100	0.56	0.58
	2	10	100	0.57	
	3	10	100	0.59	
	4	10	100	0.60	
APG-EA Diluent Water	1	10	100	0.59	0.57
	2	10	100	0.56	
	3	9	90	0.57	
	4	10	100	0.57	
10	1	10	100	0.53	0.55
	2	9	90	0.57	
	3	9	90	0.59	
	4	10	100	0.52	
18	1	8	80	0.57	0.56
	2	9	90	0.58	
	3	10	100	0.51	
	4	9	90	0.56	
32	1	9	90	0.52	0.54
	2	8	80	0.54	
	3	7	70	0.54	
	4	10	100	0.55	
56	1	0	00	0.00	0.29
	2	0	00	0.00	
	3	3	30	0.30	
	4	2	20	0.28	
100	1	0	0		
	2	0	0		
	3	0	0		
	4	0	0		

TABLE A31-4. FATHEAD MINNOW BEACH POINT RAW GROUNDWATER TOXICITY  
TEST STATISTICAL ANALYSIS (TEST NO. 3) - LARVAL  
SURVIVAL AFTER 7 DAYS OF EXPOSURE<sup>a</sup>

---

## Data Transformation:

Arc sine square root

### Chi-Square Test for Normality:

Calculated test statistic:	4.10
Alpha value:	0.01
Critical Value:	13.28
Conclusion:	Fail to reject the null hypothesis that the data are normally distributed

### Bartlett's Test for Homogeneity of Variances:

Data failed to meet homogeneity of variance test because at least one group had zero variance.

### Steel's Many-One Rank Test:

Calculated test statistic:	See Table A31-5
Alpha value:	0.05
Critical Value:	10.0
Conclusion:	Reject the null hypothesis that all groups are equal

---

<sup>a</sup> The 100% raw Beach Point groundwater treatment was not included in the statistical analyses because all organisms died during the test.

TABLE A31-5. FATHEAD MINNOW BEACH POINT RAW GROUNDWATER TOXICITY TEST STATISTICAL ANALYSIS (TEST NO. 3) - RESULTS OF STEEL'S MANY-ONE RANK TEST ON LARVAL SURVIVAL AFTER 7 DAYS OF EXPOSURE

Conc (% by Vol)	No. of Reps	Mean Survival (%) <sup>a</sup>	Rank Sum	Significance
UMD/WREC Control	4	100		
APG-EA Diluent Water	4	97.5	16.0	
10	4	95.0	14.0	
18	4	90.0	12.0	
32	4	85.0	12.0	
56	4	12.5	10.0	*

<sup>a</sup> Values given are actual percent survival means rather than arc sine square root transformed means which were used in the statistical analysis.

\* Significantly different at alpha = 0.05 (Steel's critical value = 10.0).

TABLE A31-6. FATHEAD MINNOW BEACH POINT RAW GROUNDWATER TOXICITY  
TEST STATISTICAL ANALYSIS (TEST NO. 3) - DRY WEIGHT  
OF LARVAE AFTER 7 DAYS OF EXPOSURE<sup>a</sup>

---

## Data Transformation:

None

### Chi-Square Test for Normality:

Calculated test statistic:	4.96
Alpha value:	0.01
Critical value:	13.28
Conclusion:	Fail to reject the null hypothesis that the data are normally distributed

### Bartlett's Test for Homogeneity of Variances:

Calculated test statistic:	4.41
Alpha value:	0.01
Critical value:	13.28
Conclusion:	Fail to reject the null hypothesis that the variances are homogenous

### ANOVA:

Calculated test statistic:	2.20
Alpha value:	0.05
Critical value:	3.06
Conclusion:	Fail to reject the null hypothesis that all groups are equal

---

<sup>a</sup> The 56% buffered Beach Point groundwater treatment was not included in the statistical analyses because all concentrations above the NOEC for survival are excluded from the hypothesis test for growth effects.

## APPENDIX 32

### FATHEAD MINNOW ACUTE AND 7-DAY SURVIVAL AND GROWTH TEST CONDUCTED ON BEACH POINT BUFFERED (pH $\approx$ 7) GROUNDWATER (WELL CC-33B) (TEST NO. 3)

Test Method:	EPA/600/4-89/001 (Weber et al., 1989)
Type of Test:	Static renewal (every 24 h)
Date:	August 24-31, 1993
Investigator:	S.D. Turley
Laboratory:	UMD/WREC
Groundwater:	
Source:	APG-EA Beach Point Well CC-33B
Chemical Characteristics:	See Appendix 48
Dilution Water:	
Source:	20% Perrier: 80% RO water
Chemical Characteristics:	See Table A32-1
Test Organism:	
Scientific Name:	<u>Pimephales promelas</u>
Dry Weight:	0.58 mg (mean weight of controls at end of test)
Age at Start of Test:	<24 h
Source:	UMD/WREC culture
Experimental Chambers:	
Material:	600 mL glass beaker
Test Solution Volume:	400 mL
No. Organisms/Replicate:	10
No. Organisms/Treatment:	40
Loading:	<0.5 g/L
Lighting:	Fluorescent; 60-85 foot candles
Aeration:	Prior to renewals

pH Buffer:	10 N NaOH
Endpoints:	Mortality; growth
Water Quality:	Table A32-1

---

Results:

Mortality:

96-h Exposure:

The data for the 96-h LC50 were obtained from the 7-d study. The buffered groundwater was not toxic to the larvae. The data are summarized in Table A32-2.

7-d Exposure:

The survival of fathead minnow larvae was not affected after 7 days of exposure to Beach Point buffered groundwater (Tables A32-3 and A32-4).

Growth:

The growth of fathead minnow larvae was not affected after 7 days of exposure to Beach Point buffered groundwater (Tables A32-3 and A32-5).



TABLE A32-1. SUMMARY OF THE BEACH POINT BUFFERED GROUNDWATER  
BIOASSAY TEST WATER QUALITY DATA FOR THE FATHEAD  
MINNOW 7-DAY TEST (TEST NO. 3) - DISSOLVED OXYGEN  
(MG/L)

	<u>Test Concentrations (Percent Groundwater by Volume)</u>					
	0	10	18	32	56	100
<u>Day 0</u>						
0 H	8.0	7.8	7.5	7.2	7.0	5.5
<u>Day 1</u>						
0 H	8.3	7.4	7.5	7.2	7.0	7.0
24 H	5.5	5.5	5.6	5.4	5.5	5.0
<u>Day 2</u>						
0 H	8.1	7.8	7.6	7.3	7.3	5.3
24 H	6.0	5.8	6.2	6.0	6.0	6.5
<u>Day 3</u>						
0 H	8.2	7.7	7.5	7.2	7.3	6.1
24 H	6.0	6.0	5.9	6.6	6.3	6.5
<u>Day 4</u>						
0 H	8.1	7.8	7.6	7.4	7.5	6.5
24 H	6.0	5.6	5.8	5.6	6.0	6.0
<u>Day 5</u>						
0 H	8.3	7.9	7.7	7.5	7.4	6.8
24 H	6.2	5.8	5.9	5.8	6.1	6.3
<u>Day 6</u>						
0 H	8.4	8.1	7.9	7.6	7.3	5.0
24 H	6.1	6.0	6.0	5.9	6.0	6.1
<u>Day 7</u>						
24 H	6.3	6.1	6.1	5.8	5.9	6.0

TABLE A32-1. (CONTINUED) - pH (STANDARD UNITS)

	<u>Test Concentrations (Percent Groundwater by Volume)</u>					
	0	10	18	32	56	100
<u>Day 0</u>						
0 H	7.99	7.53	7.75	7.83	7.84	7.69
<u>Day 1</u>						
0 H	7.30	7.44	7.63	7.71	7.67	7.57
24 H	7.09	7.16	7.19	7.22	7.29	7.41
<u>Day 2</u>						
0 H	8.06	7.96	7.89	7.81	7.60	7.57
24 H	7.53	7.09	7.20	7.30	7.38	7.59
<u>Day 3</u>						
0 H	7.75	7.85	8.00	8.07	8.04	7.75
24 H	7.09	7.11	7.24	7.45	7.43	7.43
<u>Day 4</u>						
0 H	7.80	7.77	7.79	7.90	7.88	7.57
24 H	7.08	7.21	7.41	7.56	7.65	7.79
<u>Day 5</u>						
0 H	7.57	7.29	7.40	7.59	7.69	7.60
24 H	7.15	7.21	7.41	7.55	7.70	7.84
<u>Day 6</u>						
0 H	7.85	7.53	7.69	7.78	7.79	7.75
24 H	7.29	7.30	7.45	7.48	7.53	7.75
<u>Day 7</u>						
24 H	7.22	7.25	7.38	7.52	7.61	7.71

TABLE A32-1. (CONTINUED) - CONDUCTIVITY ( $\mu$ MHOS/CM)

<u>Test Concentrations (Percent Groundwater by Volume)</u>		
	<u>0</u>	<u>100</u>
<u>Day 0</u>		
0 H	170	2000
<u>Day 1</u>		
0 H	160	1950
<u>Day 2</u>		
0 H	160	1625
<u>Day 3</u>		
0 H	160	1800
<u>Day 4</u>		
0 H	160	1900
<u>Day 5</u>		
0 H	170	1850
<u>Day 6</u>		
0 H	160	1925
<u>Day 7</u>		
24 H	150	1900

TABLE A32-1. (CONTINUED) - ALKALINITY (MG/L AS CaCO<sub>3</sub>)

	<u>Test Concentrations (Percent Groundwater by Volume)</u>	
	0	100
<u>Day 0</u>		
0 H	50	90
<u>Day 1</u>		
0 H	55	100
<u>Day 2</u>		
0 H	55	75
<u>Day 3</u>		
0 H	50	85
<u>Day 4</u>		
0 H	55	80
<u>Day 5</u>		
0 H	50	80
<u>Day 6</u>		
0 H	55	110
<u>Day 7</u>		
24 H	55	100

TABLE A32-1. (CONTINUED) - HARDNESS (MG/L AS CaCO<sub>3</sub>)

<u>Test Concentrations (Percent Groundwater by Volume)</u>		
	<u>0</u>	<u>100</u>
<u>Day 0</u>		
0 H	52	228
<u>Day 1</u>		
0 H	50	240
<u>Day 2</u>		
0 H	52	194
<u>Day 3</u>		
0 H	52	210
<u>Day 4</u>		
0 H	50	220
<u>Day 5</u>		
0 H	54	230
<u>Day 6</u>		
0 H	50	164
<u>Day 7</u>		
24 H	54	184

TABLE A32-2. FATHEAD MINNOW BEACH POINT BUFFERED GROUNDWATER  
TOXICITY TEST DATA (TEST NO. 3) - SURVIVAL AFTER 96  
HOURS OF EXPOSURE

Concentration (% Groundwater by Volume)	Rep	Number Tested	No. Alive at 96 Hours	Percent Alive
UMD/WREC Control	A	10	10	100
	B	10	10	100
	C	10	10	100
	D	10	10	100
10	A	10	10	100
	B	10	10	100
	C	10	9	90
	D	10	10	100
18	A	10	10	100
	B	10	10	100
	C	10	10	100
	D	10	10	100
32	A	10	9	90
	B	10	10	100
	C	10	10	100
	D	10	10	100
56	A	10	9	90
	B	10	10	100
	C	10	9	90
	D	10	10	100
100	A	10	10	100
	B	10	9	90
	C	10	8	80
	D	10	10	100

TABLE A32-3. FATHEAD MINNOW BEACH POINT BUFFERED GROUNDWATER  
TOXICITY TEST DATA (TEST NO. 3) - LARVAL SURVIVAL  
AND DRY WEIGHT AFTER 7 DAYS OF EXPOSURE

Conc (% by Vol)	Rep	Number Larvae Alive	Percent Survival	Dry Weight (mg)	Mean Dry Weight (mg)
UMD/WREC Control	1	10	100	0.56	0.58
	2	10	100	0.57	
	3	10	100	0.59	
	4	10	100	0.60	
10	1	10	100	0.51	0.58
	2	10	100	0.59	
	3	10	100	0.59	
	4	9	90	0.61	
18	1	9	90	0.56	0.57
	2	10	100	0.59	
	3	10	100	0.61	
	4	10	100	0.53	
32	1	9	90	0.58	0.58
	2	10	100	0.60	
	3	10	100	0.58	
	4	10	100	0.56	
56	1	9	90	0.54	0.56
	2	9	90	0.54	
	3	10	100	0.59	
	4	9	90	0.56	
100	1	10	100	0.55	0.55
	2	9	90	0.56	
	3	8	80	0.54	
	4	10	100	0.56	

TABLE A32-4. FATHEAD MINNOW BEACH POINT BUFFERED GROUNDWATER  
TOXICITY TEST STATISTICAL ANALYSIS (TEST NO. 3) -  
LARVAL SURVIVAL AFTER 7 DAYS OF EXPOSURE

---

Data Transformation:

Arc sine square root

Chi-Square Test for Normality:

Calculated test statistic:	11.83
Alpha value:	0.01
Critical Value:	13.28
Conclusion:	Fail to reject the null hypothesis that the data are normally distributed

Bartlett's Test for Homogeneity of Variances:

Data failed to meet homogeneity of variance test because at least one group had zero variance.

Steel's Many-One Rank Test:

Calculated test statistics:	12.0-16.0
Alpha value:	0.05
Critical Value:	10.0
Conclusion:	Fail to reject the null hypothesis that all groups are equal

---



TABLE A32-5. FATHEAD MINNOW BEACH POINT BUFFERED GROUNDWATER  
TOXICITY TEST STATISTICAL ANALYSIS (TEST NO. 3) -  
DRY WEIGHT OF LARVAE AFTER 7 DAYS OF EXPOSURE

---

Data Transformation:

None

Chi-Square Test for Normality:

Calculated test statistic:	5.02
Alpha value:	0.01
Critical value:	13.28
Conclusion:	Fail to reject the null hypothesis that the data are normally distributed

Bartlett's Test for Homogeneity of Variances:

Calculated test statistic:	7.19
Alpha value:	0.01
Critical value:	15.09
Conclusion:	Fail to reject the null hypothesis that the variances are homogenous

ANOVA:

Calculated test statistic:	0.86
Alpha value:	0.05
Critical Value:	2.77
Conclusion:	Fail to reject the null hypothesis that all groups are equal

---

# APPENDIX 33

## FATHEAD MINNOW ACUTE AND 7-DAY SURVIVAL AND GROWTH TEST CONDUCTED ON BEACH POINT RAW (pH $\approx$ 4) GROUNDWATER (WELL CC-33B) (TEST NO. 4)

Test Method:	EPA/600/4-89/001 (Weber et al., 1989)
Type of Test:	Static renewal (every 24 h)
Date:	November 30 - December 7, 1993
Investigator:	S.D. Turley
Laboratory:	UMD/WREC
Groundwater:	
Source:	APG-EA Beach Point Well CC-33B
Chemical Characteristics:	See Appendix 48
Dilution Water:	
Source:	20% Perrier: 80% RO water
Chemical Characteristics:	See Table A33-1
Test Organism:	
Scientific Name:	<u>Pimephales promelas</u>
Dry Weight:	0.49 mg (mean dry weight of controls at end of test)
Age at Start of Test:	<24 h
Source:	UMD/WREC culture
Experimental Chambers:	
Material:	600 mL glass beaker
Test Solution Volume:	400 mL
No. Organisms/Replicate:	10
No. Organisms/Treatment:	40
Loading:	<0.5 g/L
Lighting:	Fluorescent; 60-85 foot candles

Aeration:	Prior to each renewal
Endpoints:	Mortality; growth
Water Quality:	Table A33-1

---

## Results:

### Mortality:

#### 96-h Exposure:

The data for the 96-h LC50 were obtained from the 7-d study. All larvae exposed to the 100% raw groundwater treatment died during the 96-h exposure (Table A33-2). The 96-h LC50, which was determined by the moving average angle method, is as follows:

96-h LC50 = 61.7% raw groundwater by volume (95% confidence limits = 58.06-65.93).

#### 7-d Exposure:

Significant ( $\alpha = 0.05$ ) mortality occurred to fathead minnow larvae exposed to 100% and 56% groundwater by volume for 7 d (see Tables A33-3, A33-4, and A33-5). The 7-d LC50, which was determined by the moving average angle method, is as follows:

7-d LC50 = 51.3% raw groundwater by volume (95% confidence limits = 46.27-57.57).

The NOEC and LOEC for the larval fish, based on mortality, are as follows:

NOEC = 32% raw groundwater by volume.

LOEC = 56% raw groundwater by volume.

### Growth:

The growth of fathead minnow larvae was not affected by a 7-d exposure to concentrations which ranged from 10% to 32% groundwater by volume (see Tables A33-3 and A33-6).

TABLE A33-1. SUMMARY OF THE BEACH POINT RAW GROUNDWATER BIOASSAY  
TEST WATER QUALITY DATA FOR THE FATHEAD MINNOW 7-  
DAY TEST (TEST NO. 4) - DISSOLVED OXYGEN (MG/L)

	<u>Test Concentrations (Percent Groundwater by Volume)</u>					
	0	10	18	32	56	100
<u>Day 0</u>						
0 H	8.4	8.1	8.2	7.7	7.6	7.7
<u>Day 1</u>						
0 H	8.5	8.2	8.2	8.1	8.1	7.6
24 H	8.4	8.3	8.5	8.5	8.5	8.3
<u>Day 2</u>						
0 H	8.3	8.1	8.1	8.1	8.2	
24 H	8.2	8.0	8.2	8.3	8.1	
<u>Day 3</u>						
0 H	8.4	8.3	8.3	8.0	8.2	
24 H	8.3	8.2	8.1	8.2	8.1	
<u>Day 4</u>						
0 H	8.6	8.5	8.4	8.4	8.3	
24 H	8.0	8.0	7.9	8.0	8.0	
<u>Day 5</u>						
0 H	8.7	8.4	8.3	8.3	8.3	
24 H	8.0	8.1	7.8	7.8	7.7	
<u>Day 6</u>						
0 H	8.6	8.5	8.5	8.4	8.4	
24 H	8.1	6.0	8.1	8.0	8.0	
<u>Day 7</u>						
24 H	8.0	8.1	7.9	7.9	7.9	

TABLE A33-1. (CONTINUED) - pH (STANDARD UNITS)

	<u>Test Concentrations (Percent Groundwater by Volume)</u>					
	0	10	18	32	56	100
<u>Day 0</u>						
0 H	7.59	7.34	7.00	6.71	6.22	4.01
<u>Day 1</u>						
0 H	7.83	7.59	7.30	7.01	6.63	3.97
24 H	7.57	7.61	7.59	7.58	7.39	5.45
<u>Day 2</u>						
0 H	7.33	7.22	7.12	6.91	6.95	
24 H	7.59	7.69	7.67	7.50	7.26	
<u>Day 3</u>						
0 H	7.17	7.07	7.06	7.09	6.83	
24 H	7.55	7.55	7.65	7.61	7.54	
<u>Day 4</u>						
0 H	7.79	7.59	7.55	7.19	6.66	
24 H	7.65	7.71	7.73	7.75	7.59	
<u>Day 5</u>						
0 H	7.66	7.18	7.08	6.86	6.31	
24 H	7.18	7.27	7.38	7.31	7.37	
<u>Day 6</u>						
0 H	7.71	7.62	7.35	6.93	6.60	
24 H	7.42	7.43	7.48	7.45	7.37	
<u>Day 7</u>						
24 H	7.38	7.40	7.48	7.50	7.48	

TABLE A33-1. (CONTINUED) - CONDUCTIVITY ( $\mu$ MHOS/CM)

<u>Test Concentrations (Percent Groundwater by Volume)</u>		
	<u>0</u>	<u>100</u>
<u>Day 0</u>		
0 H	240	1750
<u>Day 1</u>		
0 H	230	1650
<u>Day 2</u>		
0 H	240	1700
<u>Day 3</u>		
0 H	240	1700
<u>Day 4</u>		
0 H	250	1750
<u>Day 5</u>		
0 H	230	1700
<u>Day 6</u>		
0 H	210	1750
<u>Day 7</u>		
24 H	200	1800

TABLE A33-1. (CONTINUED) - ALKALINITY (MG/L AS CaCO<sub>3</sub>)

<u>Test Concentrations (Percent Groundwater by Volume)</u>		
	<u>0</u>	<u>100</u>
<u>Day 0</u>		
0 H	70	a
<u>Day 1</u>		
0 H	65	a
<u>Day 2</u>		
0 H	65	a
<u>Day 3</u>		
0 H	65	a
<u>Day 4</u>		
0 H	60	a
<u>Day 5</u>		
0 H	55	a
<u>Day 6</u>		
0 H	50	a
<u>Day 7</u>		
24 H	55	a

<sup>a</sup> Could not obtain measurement.

TABLE A33-1. (CONTINUED) - HARDNESS (MG/L AS CaCO<sub>3</sub>)

	<u>Test Concentrations (Percent Groundwater by Volume)</u>	
	0	100
<u>Day 0</u>		
0 H	80	a
<u>Day 1</u>		
0 H	74	a
<u>Day 2</u>		
0 H	70	a
<u>Day 3</u>		
0 H	78	a
<u>Day 4</u>		
0 H	74	a
<u>Day 5</u>		
0 H	70	a
<u>Day 6</u>		
0 H	80	a
<u>Day 7</u>		
24 H	64	a

<sup>a</sup> Could not obtain measurement.



TABLE A33-2. FATHEAD MINNOW BEACH POINT RAW GROUNDWATER TOXICITY  
TEST DATA (TEST NO. 4) - SURVIVAL AFTER 96 HOURS OF  
EXPOSURE

Concentration (% Groundwater by Volume)	Rep	Number Tested	No. Alive at 96 Hours	Percent Alive
UMD/WREC Control	A	10	10	100
	B	10	10	100
	C	10	10	100
	D	10	10	100
10	A	10	10	100
	B	10	10	100
	C	10	10	100
	D	10	10	100
18	A	10	10	100
	B	10	10	100
	C	10	10	100
	D	10	9	90
32	A	10	10	100
	B	10	9	90
	C	10	10	100
	D	10	9	90
56	A	10	9	90
	B	10	10	100
	C	10	8	80
	D	10	10	100
100	A	10	0	0
	B	10	0	0
	C	10	0	0
	D	10	0	0

TABLE A33-3. FATHEAD MINNOW BEACH POINT RAW GROUNDWATER TOXICITY  
TEST DATA (TEST NO. 4) - LARVAL SURVIVAL AND DRY  
WEIGHT AFTER 7 DAYS OF EXPOSURE

Conc (% by Vol)	Rep	Number Larvae Alive	Percent Survival	Dry Weight (mg)	Mean Dry Weight (mg)
UMD/WREC Control	1	10	100	0.46	0.49
	2	10	100	0.57	
	3	9	90	0.50	
	4	10	100	0.44	
APG-EA Diluent Water	1	10	100	0.41	0.47
	2	10	100	0.44	
	3	8	80	0.54	
	4	10	100	0.42	
10	1	10	100	0.49	0.46
	2	10	100	0.48	
	3	10	100	0.46	
	4	10	100	0.40	
18	1	10	100	0.52	0.50
	2	10	100	0.50	
	3	10	100	0.48	
	4	9	90	0.48	
32	1	9	90	0.48	0.42
	2	9	90	0.48	
	3	10	100	0.35	
	4	7	70	0.38	
56	1	5	50	0.32	0.22
	2	7	70	0.16	
	3	7	70	0.16	
	4	4	40	0.25	
100	1	0	0		
	2	0	0		
	3	0	0		
	4	0	0		

TABLE A33-4. FATHEAD MINNOW BEACH POINT RAW GROUNDWATER TOXICITY  
TEST STATISTICAL ANALYSIS (TEST NO. 4) - LARVAL  
SURVIVAL AFTER 7 DAYS OF EXPOSURE<sup>a</sup>

---

Data Transformation:

Arc sine square root

Chi-Square Test for Normality:

Calculated test statistic:	12.39
Alpha value:	0.01
Critical Value:	13.28
Conclusion:	Fail to reject the null hypothesis that the data are normally distributed

Bartlett's Test for Homogeneity of Variances:

Data failed to meet homogeneity of variance test because at least one group had zero variance.

Steel's Many-One Rank Test:

Calculated test statistic:	See Table A33-5
Alpha value:	0.05
Critical Value:	10.0
Conclusion:	Reject the null hypothesis that all groups are equal

---

<sup>a</sup> The 100% raw Beach Point groundwater treatment was not included in the statistical analyses because all organisms died during the test.

TABLE A33-5. FATHEAD MINNOW BEACH POINT RAW GROUNDWATER TOXICITY TEST STATISTICAL ANALYSIS (TEST NO. 4) - RESULTS OF STEEL'S MANY-ONE RANK TEST ON LARVAL SURVIVAL AFTER 7 DAYS OF EXPOSURE

Conc (% by Vol)	No. of Reps	Mean Survival (%) <sup>a</sup>	Rank Sum	Significance
UMD/WREC Control	4	97.5		
APG-EA Diluent Water	4	95.0	17.5	
10	4	100.0	20.0	
18	4	97.5	18.0	
32	4	87.5	13.5	
56	4	57.5	10.0	*

<sup>a</sup> Values given are actual percent survival means rather than arc sine square root transformed means which were used in the statistical analysis.

\* Significantly different at alpha = 0.05 (Steel's critical value = 10.0).

TABLE A33-6. FATHEAD MINNOW BEACH POINT RAW GROUNDWATER TOXICITY  
TEST STATISTICAL ANALYSIS (TEST NO. 4) - DRY WEIGHT  
OF LARVAE AFTER 7 DAYS OF EXPOSURE<sup>a</sup>

---

Data Transformation:

None

Chi-Square Test for Normality:

Calculated test statistic:	8.16
Alpha value:	0.01
Critical value:	13.28
Conclusion:	Fail to reject the null hypothesis that the data are normally distributed

Bartlett's Test for Homogeneity of Variances:

Calculated test statistic:	4.77
Alpha value:	0.01
Critical value:	15.09
Conclusion:	Fail to reject the null hypothesis that the variances are homogenous

ANOVA:

Calculated test statistic:	1.33
Alpha value:	0.05
Critical value:	3.06
Conclusion:	Fail to reject the null hypothesis that all groups are equal

---

<sup>a</sup> The 56% buffered Beach Point groundwater treatment was not included in the statistical analyses because all concentrations above the NOEC for survival are excluded from the hypothesis test for growth effects.

## APPENDIX 34

### FATHEAD MINNOW ACUTE AND 7-DAY SURVIVAL AND GROWTH TEST CONDUCTED ON BEACH POINT BUFFERED (pH $\approx$ 7) GROUNDWATER (WELL CC-33B) (TEST NO. 4)

Test Method: EPA/600/4-89/001  
(Weber et al., 1989)

Type of Test: Static renewal (every 24 h)

Date: November 30 - December 7, 1993

Investigator: S.D. Turley

Laboratory: UMD/WREC

Groundwater:

Source: APG-EA Beach Point Well CC-33B

Chemical Characteristics: See Appendix 48

Dilution Water:

Source: 20% Perrier: 80% RO water

Chemical Characteristics: See Table A34-1

Test Organism:

Scientific Name: Pimephales promelas

Dry Weight: 0.49 mg (mean dry weight of controls at end of test)

Age at Start of Test: <24 h

Source: UMD/WREC culture

Experimental Chambers:

Material: 600 mL glass beaker

Test Solution Volume: 400 mL

No. Organisms/Replicate: 10

No. Organisms/Treatment: 40

Loading: <0.5 g/L

Lighting: Fluorescent; 60-85 foot candles

Aeration: Prior to renewals

pH Buffer:	10 N NaOH
Endpoints:	Mortality; growth
Water Quality:	Table A34-1

---

Results:

Mortality:

96-h Exposure:

The data for the 96-h LC50 were obtained from the 7-d study. The buffered groundwater was not toxic to the larvae. The data are summarized in Table A34-2.

7-d Exposure:

The survival of fathead minnow larvae was not affected after 7 days of exposure to Beach Point buffered groundwater (Tables A34-3 and A34-4).

Growth:

The growth of fathead minnow larvae was not affected after 7 days of exposure to Beach Point buffered groundwater (Tables A34-3 and A34-5).

TABLE A34-1. SUMMARY OF THE BEACH POINT BUFFERED GROUNDWATER  
BIOASSAY TEST WATER QUALITY DATA FOR THE FATHEAD  
MINNOW 7-DAY TEST (TEST NO. 4) - DISSOLVED OXYGEN  
(MG/L)

	<u>Test Concentrations (Percent Groundwater by Volume)</u>					
	0	10	18	32	56	100
<u>Day 0</u>						
0 H	8.4	8.1	8.2	8.0	7.7	7.6
<u>Day 1</u>						
0 H	8.5	8.2	8.0	8.1	8.1	8.0
24 H	8.4	8.3	8.3	8.0	8.1	7.7
<u>Day 2</u>						
0 H	8.3	8.1	8.0	8.0	7.9	8.3
24 H	8.2	8.4	8.2	7.1	7.9	7.5
<u>Day 3</u>						
0 H	8.4	8.0	8.0	8.1	7.9	7.5
24 H	8.3	8.0	8.3	8.4	8.2	8.3
<u>Day 4</u>						
0 H	8.6	8.0	8.1	8.1	7.7	7.7
24 H	8.0	7.9	7.9	8.1	8.1	8.1
<u>Day 5</u>						
0 H	8.7	8.1	8.2	8.1	8.3	8.3
24 H	8.0	7.9	8.0	8.1	8.0	7.9
<u>Day 6</u>						
0 H	8.6	8.3	8.4	8.0	8.4	8.5
24 H	8.1	7.8	8.0	8.0	7.8	7.6
<u>Day 7</u>						
24 H	8.0	7.9	7.8	7.8	7.7	7.7



TABLE A34-1. (CONTINUED) - pH (STANDARD UNITS)

		<u>Test Concentrations (Percent Groundwater by Volume)</u>					
		0	10	18	32	56	100
<u>Day 0</u>							
0 H		7.59	7.67	7.77	7.73	7.54	7.08
<u>Day 1</u>							
0 H		7.57	7.68	7.80	7.82	7.89	7.21
24 H		7.57	7.40	7.35	7.63	7.64	7.62
<u>Day 2</u>							
0 H		7.33	7.58	7.68	7.77	7.23	7.49
24 H		7.59	7.50	7.44	7.70	7.60	7.65
<u>Day 3</u>							
0 H		7.17	7.61	7.77	7.89	7.82	7.69
24 H		7.55	7.78	7.84	7.86	7.90	7.85
<u>Day 4</u>							
0 H		7.79	7.74	7.98	8.06	8.14	7.70
24 H		7.82	7.82	7.88	7.99	7.96	7.98
<u>Day 5</u>							
0 H		7.39	7.36	7.49	7.52	7.46	7.11
24 H		7.18	7.25	7.36	7.40	7.43	7.55
<u>Day 6</u>							
0 H		7.71	7.35	7.69	7.59	7.55	7.39
24 H		7.56	7.45	7.49	7.66	7.65	7.60
<u>Day 7</u>							
24 H		7.38	7.43	7.63	7.60	7.74	7.76

TABLE A34-1. (CONTINUED) - CONDUCTIVITY ( $\mu$ MHOS/CM)

	<u>Test Concentrations (Percent Groundwater by Volume)</u>	
	0	100
<u>Day 0</u>		
0 H	240	1750
<u>Day 1</u>		
0 H	230	1650
<u>Day 2</u>		
0 H	240	1700
<u>Day 3</u>		
0 H	240	1700
<u>Day 4</u>		
0 H	250	1750
<u>Day 5</u>		
0 H	230	1700
<u>Day 6</u>		
0 H	210	1750
<u>Day 7</u>		
24 H	210	1700

TABLE A34-1. (CONTINUED) - ALKALINITY (MG/L AS CaCO<sub>3</sub>)

<u>Test Concentrations (Percent Groundwater by Volume)</u>		
	<u>0</u>	<u>100</u>
<u>Day 0</u>		
0 H	70	55
<u>Day 1</u>		
0 H	65	50
<u>Day 2</u>		
0 H	65	55
<u>Day 3</u>		
0 H	65	60
<u>Day 4</u>		
0 H	60	55
<u>Day 5</u>		
0 H	55	50
<u>Day 6</u>		
0 H	50	60
<u>Day 7</u>		
24 H	55	65

TABLE A34-1. (CONTINUED) - HARDNESS (MG/L AS CaCO<sub>3</sub>)

	<u>Test Concentrations (Percent Groundwater by Volume)</u>	
	0	100
<u>Day 0</u>		
0 H	80	210
<u>Day 1</u>		
0 H	74	200
<u>Day 2</u>		
0 H	70	200
<u>Day 3</u>		
0 H	78	210
<u>Day 4</u>		
0 H	74	220
<u>Day 5</u>		
0 H	70	220
<u>Day 6</u>		
0 H	80	198
<u>Day 7</u>		
24 H	70	194

TABLE A34-2. FATHEAD MINNOW BEACH POINT BUFFERED GROUNDWATER  
TOXICITY TEST DATA (TEST NO. 4) - SURVIVAL AFTER 96  
HOURS OF EXPOSURE

Concentration (% Groundwater by Volume)	Rep	Number Tested	No. Alive at 96 Hours	Percent Alive
UMD/WREC Control	A	10	10	100
	B	10	10	100
	C	10	10	100
	D	10	10	100
10	A	10	10	100
	B	10	10	100
	C	10	10	100
	D	10	10	100
18	A	10	7	70
	B	10	10	100
	C	10	10	100
	D	10	10	100
32	A	10	10	100
	B	10	10	100
	C	10	10	100
	D	10	10	100
56	A	10	10	100
	B	10	10	100
	C	10	10	100
	D	10	10	100
100	A	10	10	100
	B	10	10	100
	C	10	10	100
	D	10	9	90

TABLE A34-3. FATHEAD MINNOW BEACH POINT BUFFERED GROUNDWATER  
TOXICITY TEST DATA (TEST NO. 4) - LARVAL SURVIVAL  
AND DRY WEIGHT AFTER 7 DAYS OF EXPOSURE

Conc (% by Vol)	Rep	Number Larvae Alive	Percent Survival	Dry Weight (mg)	Mean Dry Weight (mg)
UMD/WREC Control	1	10	100	0.46	0.49
	2	10	100	0.57	
	3	9	90	0.50	
	4	10	100	0.44	
10	1	10	100	0.41	0.48
	2	9	90	0.49	
	3	10	100	0.45	
	4	10	100	0.57	
18	1	6	60	0.27	0.43
	2	9	90	0.47	
	3	8	80	0.57	
	4	10	100	0.41	
32	1	8	80	0.44	0.44
	2	10	100	0.40	
	3	9	90	0.48	
	4	10	100	0.44	
56	1	8	80	0.52	0.49
	2	9	90	0.45	
	3	8	80	0.48	
	4	8	80	0.51	
100	1	10	100	0.51	0.49
	2	8	80	0.50	
	3	8	80	0.49	
	4	8	80	0.46	

TABLE A34-4. FATHEAD MINNOW BEACH POINT BUFFERED GROUNDWATER  
TOXICITY TEST STATISTICAL ANALYSIS (TEST NO. 4) -  
LARVAL SURVIVAL AFTER 7 DAYS OF EXPOSURE

---

Data Transformation:

Arc sine square root

Chi-Square Test for Normality:

Calculated test statistic:	7.60
Alpha value:	0.01
Critical Value:	13.28
Conclusion:	Fail to reject the null hypothesis that the data are normally distributed

Bartlett's Test for Homogeneity of Variances:

Calculated test statistic:	5.52
Alpha value:	0.01
Critical value:	15.09
Conclusion:	Fail to reject the null hypothesis that the data are homogenous

ANOVA:

Calculated test statistics:	2.36
Alpha value:	0.05
Critical Value:	2.77
Conclusion:	Fail to reject the null hypothesis that all groups are equal

---

TABLE A34-5. FATHEAD MINNOW BEACH POINT BUFFERED GROUNDWATER  
TOXICITY TEST STATISTICAL ANALYSIS (TEST NO. 4) -  
DRY WEIGHT OF LARVAE AFTER 7 DAYS OF EXPOSURE

---

Data Transformation:

None

Chi-Square Test for Normality:

Calculated test statistic:	3.78
Alpha value:	0.01
Critical value:	13.28
Conclusion:	Fail to reject the null hypothesis that the data are normally distributed

Bartlett's Test for Homogeneity of Variances:

Calculated test statistic:	10.78
Alpha value:	0.01
Critical value:	15.09
Conclusion:	Fail to reject the null hypothesis that the variances are homogenous

ANOVA:

Calculated test statistic:	0.75
Alpha value:	0.05
Critical Value:	2.77
Conclusion:	Fail to reject the null hypothesis that all groups are equal

---



## APPENDIX 35

### JAPANESE MEDAKA 96-H ACUTE TEST CONDUCTED ON BEACH POINT RAW (pH $\approx$ 4) GROUNDWATER (WELL CC-33B)

Test Method:	EPA/600/4-90/027 (Weber, 1991)
Type of Test:	Static renewal (every 24 h)
Date:	November 30 - December 4, 1993
Investigators:	R. S. Herriott and S. D. Turley
Laboratory:	UMD/WREC
Groundwater:	
Source:	APG-EA Beach Point Well CC-33B
Chemical Characteristics:	See Appendix 48
Dilution Water:	
Source:	WREC non-chlorinated well water
Chemical Characteristics:	See Table A35-1
Test Organism:	
Scientific Name:	<u>Oryzias latipes</u>
Age at Start of Test:	22 days old
Source:	Ft. Detrick BRDL culture
Experimental Chambers:	
Material:	Glass beakers
Size:	600 mL
Volume:	400 mL
No. Organisms/Replicate:	10
No. Organisms/Treatment:	20
Loading:	<0.5 g/L
Lighting:	Fluorescent; 60-85 foot candles
Aeration:	None

Endpoint:

Mortality

Water Quality:

Table A35-1

---

Results:

100% Beach Point raw groundwater killed 35% of the Japanese medaka fry in 96 h (Table A35-2); thus, a 96-h LC50 could not be calculated.

TABLE A35-1. SUMMARY OF THE BEACH POINT RAW GROUNDWATER BIOASSAY  
WATER QUALITY DATA FOR THE JAPANESE MEDAKA 96-H  
TEST - DISSOLVED OXYGEN (MG/L)

		<u>Test Concentrations (Percent Groundwater by Volume)</u>					
		0	10	18	32	56	100
<u>Day 0</u>							
0 H		8.5	8.2	8.2	7.9	8.0	8.2
<u>Day 1</u>							
0 H		8.0	7.9	8.0	8.0	7.7	7.5
24 H		6.7	6.7	7.3	7.0	7.1	7.5
<u>Day 2</u>							
0 H		8.3	8.0	8.2	8.0	8.0	8.2
24 H		8.0	8.0	7.9	7.8	7.9	8.1
<u>Day 3</u>							
0 H		8.4	8.3	8.1	7.9	7.8	8.0
24 H		8.0	8.1	8.1	7.8	8.0	8.1
<u>Day 4</u>							
24 H		8.1	8.1	7.9	7.7	8.0	7.7

TABLE A35-1. (CONTINUED) - pH (STANDARD UNITS)

	<u>Test Concentrations (Percent Groundwater by Volume)</u>					
	0	10	18	32	56	100
<u>Day 0</u>						
0 H	7.70	7.62	7.44	7.25	6.73	4.01
<u>Day 1</u>						
0 H	7.70	7.48	7.07	6.94	6.48	3.97
24 H	7.53	7.56	7.56	7.50	7.40	5.40
<u>Day 2</u>						
0 H	7.66	7.50	7.00	6.93	6.61	3.97
24 H	7.62	7.66	7.75	7.63	7.51	5.47
<u>Day 3</u>						
0 H	7.79	7.59	7.28	6.94	6.58	3.91
24 H	7.83	7.87	7.96	7.76	7.58	5.50
<u>Day 4</u>						
24 H	8.13	8.02	7.96	7.85	7.76	5.41

TABLE A35-1. (CONTINUED) - CONDUCTIVITY ( $\mu$ MHOS/CM)

<u>Test Concentrations (Percent Groundwater by Volume)</u>		
	0	100
<u>Day 0</u>		
0 H	280	1750
<u>Day 1</u>		
0 H	270	1700
<u>Day 2</u>		
0 H	270	1800
<u>Day 3</u>		
0 H	270	1700

TABLE A35-1. (CONTINUED) - ALKALINITY (MG/L as CaCO<sub>3</sub>)

	<u>Test Concentrations (Percent Groundwater by Volume)</u>	
	0	100
<u>Day 0</u>		
0 H	75	a
<u>Day 1</u>		
0 H	70	a
<u>Day 2</u>		
0 H	75	a
<u>Day 3</u>		
0 H	70	a

a Could not obtain measurement.

TABLE A35-1. (CONTINUED) - HARDNESS (MG/L AS  $\text{CaCO}_3$ )

<u>Test Concentrations (Percent Groundwater by Volume)</u>		
	0	100
<u>Day 0</u>		
0 H	60	a
<u>Day 1</u>		
0 H	55	a
<u>Day 2</u>		
0 H	60	a
<u>Day 3</u>		
0 H	64	a

<sup>a</sup> Could not obtain measurement.

TABLE A35-2. JAPANESE MEDAKA BEACH POINT RAW GROUNDWATER 96-H  
TOXICITY TEST - PERCENT FRY SURVIVAL AFTER 96  
HOURS OF EXPOSURE

Concentration (% by Volume)	Rep	Number Tested	No. Alive at End of Test	Percent Alive
UM/WREC Control	1	10	10	100
	2	10	10	100
APG-EA Diluent Water	1	10	10	100
	2	10	10	100
10	1	10	10	100
	2	10	10	100
18	1	10	10	100
	2	10	10	100
32	1	10	10	100
	2	10	9	90
56	1	10	10	100
	2	10	10	100
100	1	10	6	60
	2	10	7	70



APPENDIX 36

LIST OF DATA REPORTS FOR THE AMES ASSAYS CONDUCTED  
ON THE BEACH POINT HISTOPATHOLOGY EXPOSURE  
TANKS AND APG-EA DILUENT WATER

Table A36-1. AMES REPORTS FOR TEST NO. 1 (SAMPLES TAKEN AT BEACH POINT ON APRIL 14, 1993)

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Lawlor, T.E. 1993. Mutagenicity test on water sample APG-EA Beach Pt. 10% groundwater in the Salmonella/mammalian-microsome reverse mutation assay (Ames test) modified for direct water samples. Final Report. HWA Study No. 15617-0-401W. Hazleton Washington, Inc., Vienna, VA.

Lawlor, T.E. 1993. Mutagenicity test on an extract of the water sample APG-EA Beach Pt. 10% groundwater in the Salmonella/mammalian-microsome reverse mutation assay (Ames test) modified for XAD-2 resin extracts. Final Report. HWA Study No. 15617-1-401X. Hazleton Washington, Inc., Vienna, VA.

Lawlor, T.E. 1993. Mutagenicity test on water sample APG-EA Beach Pt. 1% groundwater in the Salmonella/mammalian-microsome reverse mutation assay (Ames test) modified for direct water samples. Final Report. HWA Study No. 15616-0-401W. Hazleton Washington, Inc., Vienna, VA.

Lawlor, T.E. 1993. Mutagenicity test on an extract of the water sample APG-EA Beach Pt. 1% groundwater in the Salmonella/mammalian-microsome reverse mutation assay (Ames test) modified for XAD-2 resin extracts. Final Report. HWA Study No. 15616-1-401X. Hazleton Washington, Inc., Vienna, VA.

Lawlor, T.E. 1993. Mutagenicity test on water sample APG-EA diluent water in the Salmonella/mammalian-microsome reverse mutation assay (Ames test) modified for direct water samples. Final Report. HWA Study No. 15615-0-401W. Hazleton Washington, Inc., Vienna, VA.

Lawlor, T.E. 1993. Mutagenicity test on water sample APG-EA diluent water in the Salmonella/mammalian-microsome reverse mutation assay (Ames test) modified for XAD-2 resin extracts. Final Report. HWA Study No. 15615-1-401W. Hazleton Washington, Inc., Vienna, VA.

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Table A36-2. AMES REPORTS FOR TEST NO. 2 (SAMPLES TAKEN AT BEACH POINT ON JUNE 2, 1993)

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Lawlor, T.E. 1993. Mutagenicity test on water sample APG-EA Beach Pt. 10% groundwater in the Salmonella/mammalian-microsome reverse mutation assay (Ames test) modified for direct water samples. Final Report. HWA Study No. 15676-0-401W. Hazleton Washington, Inc., Vienna, VA.

Lawlor, T.E. 1993. Mutagenicity test on an extract of the water sample APG-EA Beach Pt. 10% groundwater in the Salmonella/mammalian-microsome reverse mutation assay (Ames test) modified for XAD-2 resin extracts. Final Report. HWA Study No. 15676-1-401X. Hazleton Washington, Inc., Vienna, VA.

Lawlor, T.E. 1993. Mutagenicity test on water sample APG-EA Beach Pt. 1% groundwater in the Salmonella/mammalian-microsome reverse mutation assay (Ames test) modified for direct water samples. Final Report. HWA Study No. 15677-0-401W. Hazleton Washington, Inc., Vienna, VA.

Lawlor, T.E. 1993. Mutagenicity test on an extract of the water sample APG-EA Beach Pt. 1% groundwater in the Salmonella/mammalian-microsome reverse mutation assay (Ames test) modified for XAD-2 resin extracts. Final Report. HWA Study No. 15677-1-401X. Hazleton Washington, Inc., Vienna, VA.

Lawlor, T.E. 1993. Mutagenicity test on water sample APG-EA diluent/control water in the Salmonella/mammalian-microsome reverse mutation assay (Ames test) modified for direct water samples. Final Report. HWA Study No. 15678-0-401W. Hazleton Washington, Inc., Vienna, VA.

Lawlor, T.E. 1993. Mutagenicity test on an extract of the water sample APG-EA diluent/control water in the Salmonella/mammalian-microsome reverse mutation assay (Ames test) modified for XAD-2 resin extracts. Final Report. HWA Study No. 15678-1-401W. Hazleton Washington, Inc., Vienna, VA.

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Table A36-3. AMES REPORTS FOR TEST NO. 3 (SAMPLES TAKEN AT BEACH POINT ON AUGUST 23, 1993)

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- Lawlor, T.E. 1993. Mutagenicity test on water sample 100% groundwater APG-EA Beach Pt. Well 33B in the Salmonella/mammalian-microsome reverse mutation assay (Ames test) modified for direct water samples. Final Report. HWA Study No. 15817-0-401W. Hazleton Washington, Inc., Vienna, VA.
- Lawlor, T.E. 1993. Mutagenicity test on an extract of the water sample 100% groundwater APG-EA Beach Pt. Well 33B in the Salmonella/mammalian-microsome reverse mutation assay (Ames test) modified for XAD-2 resin extracts. Final Report. HWA Study No. 15817-1-401X. Hazleton Washington, Inc., Vienna, VA.
- Lawlor, T.E. 1993. Mutagenicity test on water sample 10% groundwater APG-EA Beach Pt. Well 33B in the Salmonella/mammalian-microsome reverse mutation assay (Ames test) modified for direct water samples. Final Report. HWA Study No. 15816-0-401W. Hazleton Washington, Inc., Vienna, VA.
- Lawlor, T.E. 1993. Mutagenicity test on an extract of the water sample 10% groundwater APG-EA Beach Pt. Well 33B in the Salmonella/mammalian-microsome reverse mutation assay (Ames test) modified for XAD-2 resin extracts. Final Report. HWA Study No. 15816-1-401X. Hazleton Washington, Inc., Vienna, VA.
- Lawlor, T.E. 1993. Mutagenicity test on water sample APG-EA diluent/control water in the Salmonella/mammalian-microsome reverse mutation assay (Ames test) modified for direct water samples. Final Report. HWA Study No. 15815-0-401W. Hazleton Washington, Inc., Vienna, VA.
- Lawlor, T.E. 1993. Mutagenicity test on an extract of the water sample APG-EA diluent/control water in the Salmonella/mammalian-microsome reverse mutation assay (Ames test) modified for XAD-2 resin extracts. Final Report. HWA Study No. 15815-1-401W. Hazleton Washington, Inc., Vienna, VA.
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Table A36-4. AMES REPORTS FOR TEST NO. 4 (SAMPLES TAKEN AT BEACH POINT ON NOVEMBER 30, 1993)

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Lawlor, T.E. 1994. Mutagenicity test on water sample 100% groundwater APG-EA Beach Pt. Well 33B in the Salmonella/mammalian-microsome reverse mutation assay (Ames test) modified for direct water samples. Final Report. HWA Study No. 15976-0-401W. Hazleton Washington, Inc., Vienna, VA.

Lawlor, T.E. 1994. Mutagenicity test on an extract of the water sample 100% groundwater APG-EA Beach Pt. Well 33B in the Salmonella/mammalian-microsome reverse mutation assay (Ames test) modified for XAD-2 resin extracts. Final Report. HWA Study No. 15976-1-401X. Hazleton Washington, Inc., Vienna, VA.

Lawlor, T.E. 1994. Mutagenicity test on water sample 10% groundwater APG-EA Beach Pt. Well 33B in the Salmonella/mammalian-microsome reverse mutation assay (Ames test) modified for direct water samples. Final Report. HWA Study No. 15975-0-401W. Hazleton Washington, Inc., Vienna, VA.

Lawlor, T.E. 1994. Mutagenicity test on an extract of the water sample 10% groundwater APG-EA Beach Pt. Well 33B in the Salmonella/mammalian-microsome reverse mutation assay (Ames test) modified for XAD-2 resin extracts. Final Report. HWA Study No. 15975-1-401X. Hazleton Washington, Inc., Vienna, VA.

Lawlor, T.E. 1994. Mutagenicity test on water sample APG-EA diluent/control water in the Salmonella/mammalian-microsome reverse mutation assay (Ames test) modified for direct water samples. Final Report. HWA Study No. 15974-0-401W. Hazleton Washington, Inc., Vienna, VA.

Lawlor, T.E. 1994. Mutagenicity test on an extract of the water sample APG-EA diluent/control water in the Salmonella/mammalian-microsome reverse mutation assay (Ames test) modified for XAD-2 resin extracts. Final Report. HWA Study No. 15974-1-401W. Hazleton Washington, Inc., Vienna, VA.

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## APPENDIX 37

### LIST OF DATA REPORTS FOR THE SCE ASSAYS CONDUCTED ON THE BEACH POINT HISTOPATHOLOGY EXPOSURE TANKS AND APG-EA DILUENT WATER

#### Sample taken June 2, 1993

Murli, H. 1993. Mutagenicity test on an extract of the water sample APG-EA Beach Pt. 10% GW in an in vitro cytogenetic assay measuring sister chromatid exchange in Chinese hamster ovary (CHO) cells. Final Report. HWA Study No. 15676-0-438. Hazleton Washington, Inc., Vienna, VA.

#### Sample taken July 19, 1993

Murli, H. 1993. Mutagenicity test on an extract of the water sample 100% GW (Well 33B) APG-EA Beach Pt. in an in vitro cytogenetic assay measuring sister chromatid exchange in Chinese hamster ovary (CHO) cells. Final Report. HWA Study No. 15748-0-438. Hazleton Washington, Inc., Vienna, VA.

#### Sample taken August 23, 1993

Murli, H. 1993. Mutagenicity test on an extract of the water sample 0% GW (dilution/control water) in an in vitro cytogenetic assay measuring sister chromatid exchange in Chinese hamster ovary (CHO) cells. Final Report. HWA Study No. 15818-0-438. Hazleton Washington, Inc., Vienna, VA.

#### Sample taken November 30, 1993

Murli, H. 1994. Mutagenicity test on 100% groundwater APG-EA, Beach Pt. Well 33B in an in vitro cytogenetic assay measuring sister chromatid exchange in Chinese hamster ovary (CHO) cells. Final Report. HWA Study No. 15976-0-438. Hazleton Washington, Inc., Vienna, VA.

APPENDIX 38

FROG EMBRYO TERATOGENESIS ASSAY - Xenopus (FETAX)  
CONDUCTED ON BEACH POINT RAW (pH  $\approx$ 4)  
GROUNDWATER (WELL 33B)  
(TEST NO. 1)

Test Method:	ASTM Designation E 1439-91 ASTM (1991)
Type of Test:	Static renewal (every 24 h)
Date:	April 10-14, 1993
Investigator:	S. D. Turley
Laboratory:	UMD/WREC
Groundwater:	
Source:	APG-EA Beach Point Well 33B
Chemical Characteristics:	See Appendix 48
Test Medium:	
Source:	FETAX solution
pH characteristics:	See Table A38-1
Test Organism:	
Scientific Name:	<u>Xenopus laevis</u>
Age at Start of Test:	Stage 8 blastula to stage 11 gastrulae
Source:	UMD/WREC culture
Experimental Chambers:	
Material:	Glass petri dishes
Test Solution Volume:	10 mL
No. Organisms/Replicate:	25
No. Organisms/Treatment:	Control: 100 Groundwater: 50
Loading:	n/a
Lighting:	Fluorescent; 60-85 foot candles
Aeration:	Prior to renewals

Endpoints:	Mortality; malformation
Test Temperature:	24 ± 0.2°C

---

Results:

Mortality:

The raw groundwater did not affect embryo survival. The data are summarized in Tables A38-2 and A38-3.

Malformations:

Significant ( $\alpha = 0.05$ ) embryo malformations occurred at all concentrations down to 18% raw groundwater by volume (see Tables A38-2, A38-4, and A38-5). Less than 50% malformation occurred at all test concentrations, thus, an EC50 could not be calculated (Table A38-2). The NOEC and LOEC for the embryos, based on increased numbers of malformations, are as follows:

NOEC = 10% raw groundwater by volume.  
LOEC = 18% raw groundwater by volume.

The types of malformed embryos are given in Table A38-6.



TABLE A38-1. SUMMARY OF THE BEACH POINT RAW GROUNDWATER  
BIOASSAY pH (STANDARD UNITS) DATA FOR FETAX (TEST  
NO. 1)

	<u>Test Concentrations (Percent Groundwater by Volume)</u>					
	0	10	18	32	56	100
<u>Day 0</u>						
0 H	7.51	7.31	7.11	6.71	6.12	4.10
<u>Day 1</u>						
0 H	7.48	7.24	7.01	6.54	6.00	4.19
<u>Day 2</u>						
0 H	7.56	7.36	7.20	6.77	6.03	4.02
<u>Day 3</u>						
0 H	7.59	7.39	7.18	6.59	5.96	3.98
<u>Day 4</u>						
24 H	7.54	7.33	7.13	6.65	6.03	4.07

TABLE A38-2. FETAX BEACH POINT RAW GROUNDWATER TOXICITY TEST DATA (TEST NO. 1) - PERCENT EMBRYO SURVIVAL AND MALFORMATIONS AFTER 96 HOURS OF EXPOSURE<sup>a</sup>

Conc (% by Vol)	Rep	Number Embryos Alive	Percent Survival	Number Embryos Malformed	Percent Malformed
UMD/WREC Control	1	25	100	1	4.0
	2	25	100	1	4.0
	3	24	96	0	0.0
	4	25	100	1	4.0
10	1	24	96	2	8.3
	2	23	92	3	13.0
18	1	24	96	4	16.7
	2	25	100	4	16.0
32	1	23	92	3	13.0
	2	24	96	4	16.7
56	1	24	96	4	16.7
	2	22	88	4	18.2
100	1	24	96	8	33.3
	2	23	92	13	56.5

<sup>a</sup> An APG-EA diluent water control was not run during FETAX.

TABLE A38-3. FETAX BEACH POINT RAW GROUNDWATER TOXICITY TEST  
STATISTICAL ANALYSIS (TEST NO. 1) - PERCENT EMBRYO  
SURVIVAL AFTER 96 HOURS OF EXPOSURE

---

Data Transformation:

Arc sine square root

Chi-Square Test for Normality:

Calculated test statistic:	5.69
Alpha value:	0.01
Critical value:	13.28
Conclusion:	Fail to reject the null hypothesis that the data are normally distributed

Bartlett's Test for Homogeneity of Variances:

Calculated test statistic:	0.82
Alpha value:	0.01
Critical value:	15.09
Conclusion:	Fail to reject the null hypothesis that the variances are homogenous

ANOVA:

Calculated test statistic:	2.50
Alpha value:	0.05
Critical value:	3.69
Conclusion:	Fail to reject the null hypothesis that all groups are equal

---

TABLE A38-4. FETAX BEACH POINT RAW GROUNDWATER TOXICITY TEST  
STATISTICAL ANALYSIS (TEST NO. 1) - PERCENT EMBRYO  
MALFORMATIONS AFTER 96 HOURS OF EXPOSURE

---

Data Transformation:

Arc sine square root

Chi-Square Test for Normality:

Calculated test statistic:	5.69
Alpha value:	0.01
Critical Value:	13.28
Conclusion:	Fail to reject the null hypothesis that the data are normally distributed

Bartlett's Test for Homogeneity of Variances:

Calculated test statistic:	9.95
Alpha value:	0.01
Critical value:	15.09
Conclusion:	Fail to reject the null hypothesis that the variances are homogenous

ANOVA:

Calculated test statistic:	17.20
Alpha value:	0.05
Critical value:	3.69
Conclusion:	Reject the null hypothesis that all groups are equal

Bonferroni's T-Test:

Calculated test statistic:	See Table A38-5
Alpha value:	0.05
Critical value:	2.90
Conclusion:	Reject the null hypothesis that all groups are equal

---

TABLE A38-5. FETAX BEACH POINT RAW GROUNDWATER TOXICITY TEST  
STATISTICAL ANALYSIS (TEST NO. 1) - RESULTS OF  
BONFERRONI'S T-TEST ON EMBRYO MALFORMATIONS AFTER  
96 HOURS OF EXPOSURE

Conc (% by Vol)	No. of Reps	Mean Normal Embryos (%) <sup>a</sup>	T Statistic	Significance
UMD/WREC Control	4	97.0		
10	2	89.4	2.52	
18	2	83.7	3.92	*
32	2	85.1	3.57	*
56	2	82.5	4.16	*
100	2	55.1	9.09	*

<sup>a</sup> Values given are actual percent mean normal embryos rather than arc sine square root transformed means which were used in the statistical analysis.

\* Significantly different at alpha = 0.05 (Bonferroni's critical value = 2.90).

TABLE A38-6. FETAX BEACH POINT RAW GROUNDWATER TOXICITY TEST  
DATA (TEST NO. 1) - TYPE AND NUMBER OF MALFORMED  
EMBRYOS AFTER 96 HOURS OF EXPOSURE

Malformation	Test Concentrations (% Groundwater by Volume)													
	0				10		18		32		56		100	
	<u>Rep</u>				<u>Rep</u>		<u>Rep</u>		<u>Rep</u>		<u>Rep</u>		<u>Rep</u>	
	1	2	3	4	1	2	1	2	1	2	1	2	1	2
<hr/>														
Severe														
Gut, coiling				1		1		2 2		3		1		2 5
Edema:														
Multiple						2		2 1		1 1		2		5 6
Cardiac														
Abdominal				1		1 1		1		2		1		1 2
Facial														
Cephalic														
Blisters														
Tail														
Notochord				1								1		
Fin														
Face												3		
Eye														
Brain														
Hemorrhage														
Cardiac														
Other														

APPENDIX 39

FROG EMBRYO TERATOGENESIS ASSAY - Xenopus (FETAX)  
CONDUCTED ON BEACH POINT BUFFERED (pH  $\approx$ 7)  
GROUNDWATER (WELL 33B)  
(TEST NO. 1)

Test Method:	ASTM Designation E 1439-91 ASTM (1991)
Type of Test:	Static renewal (every 24 h)
Date:	April 10-14, 1993
Investigator:	S. D. Turley
Laboratory:	UMD/WREC
Groundwater:	
Source:	APG-EA Beach Point Well 33B
Chemical Characteristics:	See Appendix 48
Test Medium:	
Source:	FETAX solution
pH characteristics:	See Table A39-1
Test Organism:	
Scientific Name:	<u>Xenopus laevis</u>
Age at Start of Test:	Stage 8 blastula to stage 11 gastrulae
Source:	UMD/WREC culture
Experimental Chambers:	
Material:	Glass petri dishes
Test Solution Volume:	10 mL
No. Organisms/Replicate:	25
No. Organisms/Treatment:	Groundwater: 50 Control: 100
Loading:	n/a
Lighting:	Fluorescent; 60-85 foot candles
Aeration:	Prior to renewals

pH Buffer:	10 N NaOH
Endpoints:	Mortality; malformations
Test Temperature:	24 ± 0.2°C

---

Results:

Mortality:

The buffered groundwater did not affect embryo survival.  
The data are summarized in Tables A39-2 and A39-3.

Malformations:

Significant ( $\alpha = 0.05$ ) embryo malformations occurred at all concentrations down to 32% buffered groundwater by volume (see Tables A39-2, A39-4, and A39-5). Less than 50% malformation occurred at all test concentrations, thus, an EC50 could not be calculated (Table A39-2). The NOEC and LOEC for the embryos, based on increased numbers of malformations, are as follows:

NOEC = 18% buffered groundwater by volume.

LOEC = 32% buffered groundwater by volume.

The types of malformed embryos are given in Table A39-6.



TABLE A39-1. SUMMARY OF THE BEACH POINT BUFFERED GROUNDWATER  
BIOASSAY pH (STANDARD UNITS) DATA FOR FETAX (TEST  
NO. 1)

<u>Test Concentrations (Percent Groundwater by Volume)</u>					
	0	18	32	56	100
<u>Day 0</u>					
0 H	7.51	7.13	6.99	7.11	6.92
<u>Day 1</u>					
0 H	7.48	7.19	7.12	7.16	7.06
<u>Day 2</u>					
0 H	7.56	7.18	7.11	7.13	7.00
<u>Day 3</u>					
0 H	7.59	7.12	7.02	7.08	6.95
<u>Day 4</u>					
24 H	7.54	7.17	7.06	7.12	6.98

TABLE A39-2. FETAX BEACH POINT BUFFERED GROUNDWATER TOXICITY  
TEST DATA (TEST NO. 1) - PERCENT EMBRYO SURVIVAL  
AND MALFORMATIONS AFTER 96 HOURS OF EXPOSURE

Conc (% by Vol)	Rep	Number Embryos Alive	Percent Survival	Number Embryos Malformed	Percent Malformed
UMD/WREC Control	1	25	100	1	4.0
	2	25	100	1	4.0
	3	24	96	0	0.0
	4	25	100	1	4.0
18	1	23	92	2	8.7
	2	25	100	2	8.0
32	1	23	92	2	8.7
	2	24	96	3	13.0
56	1	23	92	5	21.7
	2	24	96	5	20.8
100	1	24	96	4	16.7
	2	25	100	7	28.0

TABLE A39-3. FETAX BEACH POINT BUFFERED GROUNDWATER TOXICITY  
TEST STATISTICAL ANALYSIS (TEST NO. 1) - PERCENT  
EMBRYO SURVIVAL AFTER 96 HOURS OF EXPOSURE

---

Data Transformation:

Arc sine square root

Chi-Square Test for Normality:

Calculated test statistic:	4.08
Alpha value:	0.01
Critical value:	13.28
Conclusion:	Fail to reject the null hypothesis that the data are normally distributed

Bartlett's Test for Homogeneity of Variances:

Calculated test statistic:	1.44
Alpha value:	0.01
Critical value:	13.28
Conclusion:	Fail to reject the null hypothesis that the variances are homogenous

ANOVA:

Calculated test statistic:	1.60
Alpha value:	0.05
Critical value:	4.12
Conclusion:	Fail to reject the null hypothesis that all groups are equal

---

TABLE A39-4. FETAX BEACH POINT BUFFERED GROUNDWATER TOXICITY  
TEST STATISTICAL ANALYSIS (TEST NO. 1) - PERCENT  
EMBRYO MALFORMATIONS AFTER 96 HOURS OF EXPOSURE

---

Data Transformation:

Arc sine square root

Chi-Square Test for Normality:

Calculated test statistic:	4.08
Alpha value:	0.01
Critical Value:	13.28
Conclusion:	Fail to reject the null hypothesis that the data are normally distributed

Bartlett's Test for Homogeneity of Variances:

Calculated test statistic:	7.56
Alpha value:	0.01
Critical value:	13.28
Conclusion:	Fail to reject the null hypothesis that the variances are homogenous

ANOVA:

Calculated test statistic:	16.33
Alpha value:	0.05
Critical value:	4.12
Conclusion:	Reject the null hypothesis that all groups are equal

Bonferroni's T-Test:

Calculated test statistic:	See Table A39-5
Alpha value:	0.05
Critical value:	2.84
Conclusion:	Reject the null hypothesis that all groups are equal

---

TABLE A39-5. FETAX BEACH POINT BUFFERED GROUNDWATER TOXICITY TEST STATISTICAL ANALYSIS (TEST NO. 1) - RESULTS OF BONFERRONI'S T-TEST ON EMBRYO MALFORMATIONS AFTER 96 HOURS OF EXPOSURE

Conc (% by Vol)	No. of Reps	Mean Normal Embryos (%) <sup>a</sup>	T Statistic	Significance
UMD/WREC Control	4	97.0		
18	2	91.7	2.47	
32	2	89.1	3.33	*
56	2	78.7	6.41	*
100	2	77.5	6.65	*

<sup>a</sup> Values given are actual percent mean normal embryos rather than arc sine square root transformed means which were used in the statistical analysis.

\* Significantly different at alpha = 0.05 (Bonferroni's critical value = 2.84).

TABLE A39-6. FETAX BEACH POINT BUFFERED GROUNDWATER TOXICITY  
TEST DATA (TEST NO. 1) - TYPE AND NUMBER OF  
MALFORMED EMBRYOS AFTER 96 HOURS OF EXPOSURE

Malformation	Test Concentrations (% Groundwater by Volume)											
	0				18		32		56		100	
	<u>Rep</u>				<u>Rep</u>		<u>Rep</u>		<u>Rep</u>		<u>Rep</u>	
	1	2	3	4	1	2	1	2	1	2	1	2
<hr/>												
Severe												
Gut, coiling				1		1		1		2		1 1
Edema:												
Multiple						1 1		1 1		1 2		3
Cardiac												1
Abdominal				1		1				2 4		1
Facial												1 1
Cephalic												
Blisters												
Tail												
Notochord				1								1
Fin												
Face								2				1
Eye												
Brain												
Hemorrhage												
Cardiac												
Other												

APPENDIX 40

FROG EMBRYO TERATOGENESIS ASSAY - Xenopus (FETAX)  
CONDUCTED ON BEACH POINT RAW (pH  $\approx$ 4)  
GROUNDWATER (WELL 33B)  
(TEST NO. 2)

Test Method:	ASTM Designation E 1439-91 ASTM (1991)
Type of Test:	Static renewal (every 24 h)
Date:	June 3-7, 1993
Investigator:	S. D. Turley
Laboratory:	UMD/WREC
Groundwater:	
Source:	APG-EA Beach Point Well 33B
Chemical Characteristics:	See Appendix 48
Test Medium:	
Source:	FETAX solution
pH characteristics:	See Table A40-1
Test Organism:	
Scientific Name:	<u>Xenopus laevis</u>
Age at Start of Test:	Stage 8 blastula to stage 11 gastrulae
Source:	UMD/WREC culture
Experimental Chambers:	
Material:	Glass petri dishes
Test Solution Volume:	10 mL
No. Organisms/Replicate:	25
No. Organisms/Treatment:	Control: 100 Groundwater: 50
Loading:	n/a
Lighting:	Fluorescent; 60-85 foot candles
Aeration:	Prior to renewals

Endpoints:

Mortality; malformation

Test Temperature:

24 ± 0.2°C

---

Results:

Mortality:

The raw groundwater did not affect embryo survival. The data are summarized in Tables A40-2 and A40-3.

Malformations:

Significant ( $\alpha = 0.05$ ) embryo malformations occurred at all concentrations down to 18% raw groundwater by volume (see Tables A40-2, A40-4, and A40-5). The 96-h EC50 (malformations), which was determined by the moving average angle method, NOEC and LOEC for the embryos, based on increased numbers of malformations, are as follows:

96-h EC50 = 88.7% raw groundwater by volume (95% confidence limits = 71.1- 143.1).

NOEC = 10% raw groundwater by volume.

LOEC = 18% raw groundwater by volume.

The types of malformed embryos are given in Table A40-6.



TABLE A40-1. SUMMARY OF THE BEACH POINT RAW GROUNDWATER  
BIOASSAY pH (STANDARD UNITS) DATA FOR FETAX (TEST  
NO. 2)

	<u>Test Concentrations (Percent Groundwater by Volume)</u>					
	0	10	18	32	56	100
<u>Day 0</u>						
0 H	7.50	7.48	7.46	7.37	7.07	3.99
<u>Day 1</u>						
0 H	7.65	7.64	7.61	7.44	7.30	3.90
<u>Day 2</u>						
0 H	7.61	7.57	7.50	7.30	6.90	3.92
<u>Day 3</u>						
0 H	7.53	7.45	7.40	7.29	6.97	3.93
<u>Day 4</u>						
24 H	7.59	7.38	7.23	6.86	6.63	4.17

TABLE A40-2. FETAX BEACH POINT RAW GROUNDWATER TOXICITY TEST  
DATA (TEST NO. 2) - PERCENT EMBRYO SURVIVAL AND  
MALFORMATIONS AFTER 96 HOURS OF EXPOSURE<sup>a</sup>

Conc (% by Vol)	Rep	Number Embryos Alive	Percent Survival	Number Embryos Malformed	Percent Malformed
UMD/WREC Control	1	24	96	2	8.3
	2	23	92	1	4.3
	3	24	96	2	8.3
	4	24	96	2	8.3
APG-EA Diluent Water	1	24	96	2	8.3
	2	23	92	3	13.0
10	1	25	100	3	12.0
	2	23	92	2	8.7
18	1	25	100	3	12.0
	2	24	96	4	16.7
32	1	24	96	3	12.5
	2	22	88	4	18.1
56	1	22	88	6	27.3
	2	23	92	6	26.1
100	1	25	100	14	56.0
	2	24	96	13	54.2

TABLE A40-3. FETAX BEACH POINT RAW GROUNDWATER TOXICITY TEST  
STATISTICAL ANALYSIS (TEST NO. 2) - PERCENT EMBRYO  
SURVIVAL AFTER 96 HOURS OF EXPOSURE

---

Data Transformation:

Arc sine square root

Chi-Square Test for Normality:

Calculated test statistic:	7.42
Alpha value:	0.01
Critical value:	13.28
Conclusion:	Fail to reject the null hypothesis that the data are normally distributed

Bartlett's Test for Homogeneity of Variances:

Calculated test statistic:	2.03
Alpha value:	0.01
Critical value:	16.81
Conclusion:	Fail to reject the null hypothesis that the variances are homogenous

ANOVA:

Calculated test statistic:	1.33
Alpha value:	0.05
Critical value:	3.37
Conclusion:	Fail to reject the null hypothesis that all groups are equal

---

TABLE A40-4. FETAX BEACH POINT RAW GROUNDWATER TOXICITY TEST  
STATISTICAL ANALYSIS (TEST NO. 2) - PERCENT EMBRYO  
MALFORMATIONS AFTER 96 HOURS OF EXPOSURE

---

Data Transformation:

Arc sine square root

Chi-Square Test for Normality:

Calculated test statistic:	7.42
Alpha value:	0.01
Critical Value:	13.28
Conclusion:	Fail to reject the null hypothesis that the data are normally distributed

Bartlett's Test for Homogeneity of Variances:

Calculated test statistic:	4.04
Alpha value:	0.01
Critical value:	16.81
Conclusion:	Fail to reject the null hypothesis that the variances are homogenous

ANOVA:

Calculated test statistic:	42.00
Alpha value:	0.05
Critical value:	3.37
Conclusion:	Reject the null hypothesis that all groups are equal

Bonferroni's T-Test:

Calculated test statistic:	See Table A40-5
Alpha value:	0.05
Critical value:	2.94
Conclusion:	Reject the null hypothesis that all groups are equal

---

TABLE A40-5. FETAX BEACH POINT RAW GROUNDWATER TOXICITY TEST  
STATISTICAL ANALYSIS (TEST NO. 2) - RESULTS OF  
BONFERRONI'S T-TEST ON EMBRYO MALFORMATIONS AFTER  
96 HOURS OF EXPOSURE

Conc (% by Vol)	No. of Reps	Mean Normal Embryos (%) <sup>a</sup>	T Statistic	Significance
UMD/WREC Control	4	93.0		
10	2	89.5	1.61	
18	2	85.5	3.20	*
32	2	84.5	3.57	*
56	2	73.5	7.11	*
100	2	45.0	14.72	*

<sup>a</sup> Values given are actual percent mean normal embryos rather than arc sine square root transformed means which were used in the statistical analysis.

\* Significantly different at alpha = 0.05 (Bonferroni's critical value = 2.94).

TABLE A40-6. FETAX BEACH POINT RAW GROUNDWATER TOXICITY TEST  
DATA (TEST NO. 2) - TYPE AND NUMBER OF MALFORMED  
EMBRYOS AFTER 96 HOURS OF EXPOSURE<sup>a</sup>

Malformation	Test Concentrations (% Groundwater by Volume)									
	0				10		18		32	
	<u>Rep</u>				<u>Rep</u>		<u>Rep</u>		<u>Rep</u>	
	1	2	3	4	1	2	1	2	1	2
Severe									1	3
Gut, coiling							2	3	2	1
Edema:										
Multiple	2	1	1		3	2	1	1	1	1
Cardiac										
Abdominal									1	1
Facial										
Cephalic										
Blisters										
Tail										
Notochord	1	1	1							
Fin										
Face										1
Eye										
Brain										
Hemorrhage										
Cardiac										
Other										

<sup>a</sup> The APG-EA diluent water controls had the following the malformations: Rep 1- 2 embryos with multiple edema. Rep 2- 1 severe and 2 multiple edema.

APPENDIX 41

FROG EMBRYO TERATOGENESIS ASSAY - Xenopus (FETAX)  
CONDUCTED ON BEACH POINT BUFFERED (pH  $\approx$ 7)  
GROUNDWATER (WELL 33B)  
(TEST NO. 2)

Test Method:	ASTM Designation E 1439-91 ASTM (1991)
Type of Test:	Static renewal (every 24 h)
Date:	June 3-7, 1993
Investigator:	S. D. Turley
Laboratory:	UMD/WREC
Groundwater:	
Source:	APG-EA Beach Point Well 33B
Chemical Characteristics:	See Appendix 48
Test Medium:	
Source:	FETAX solution
pH characteristics:	See Table A41-1
Test Organism:	
Scientific Name:	<u>Xenopus laevis</u>
Age at Start of Test:	Stage 8 blastula to stage 11 gastrulae
Source:	UMD/WREC culture
Experimental Chambers:	
Material:	Glass petri dishes
Test Solution Volume:	10 mL
No. Organisms/Replicate:	25
No. Organisms/Treatment:	Groundwater: 50 Control: 100
Loading:	n/a
Lighting:	Fluorescent; 60-85 foot candles
Aeration:	Prior to renewals

pH Buffer:	10 N NaOH
Endpoints:	Mortality; malformations
Test Temperature:	24 ± 0.2°C

---

Results:

Mortality:

Less than 50% mortality occurred to the embryos exposed for 4 days to 100% Beach Point buffered groundwater; thus, an LC50 could not be calculated (Table A41-2). A significant increase in embryo mortality occurred at 56% and 100% buffered groundwater by volume (see Tables A41-2, A41-3 and A41-4).

Malformations:

Significant ( $\alpha = 0.05$ ) embryo malformations occurred at all concentrations down to 32% buffered groundwater by volume (see Tables A41-2, A41-4, and A41-5). Less than 50% malformation occurred at all test concentrations, thus, an EC50 could not be calculated (Table A41-2). The NOEC and LOEC for the embryos, based on increased numbers of malformations, are as follows:

NOEC = 18% buffered groundwater by volume.  
LOEC = 32% buffered groundwater by volume.

The types of malformed embryos are given in Table A41-7.



TABLE A41-1. SUMMARY OF THE BEACH POINT BUFFERED GROUNDWATER  
BIOASSAY pH (STANDARD UNITS) DATA FOR FETAX (TEST  
NO. 2)

	<u>Test Concentrations (Percent Groundwater by Volume)</u>					
	0	10	18	32	56	100
<u>Day 0</u>						
0 H	7.50	7.47	7.40	7.45	7.57	7.55
<u>Day 1</u>						
0 H	7.65	6.98	7.21	7.38	7.48	7.55
<u>Day 2</u>						
0 H	7.61	7.66	7.81	7.91	7.92	7.88
<u>Day 3</u>						
0 H	7.53	7.44	7.48	7.43	7.51	7.56
<u>Day 4</u>						
24 H	7.57	7.37	7.46	7.52	7.44	7.59

TABLE A41-2. FETAX BEACH POINT BUFFERED GROUNDWATER TOXICITY  
TEST DATA (TEST NO. 2) - PERCENT EMBRYO SURVIVAL  
AND MALFORMATIONS AFTER 96 HOURS OF EXPOSURE

Conc (% by Vol)	Rep	Number Embryos Alive	Percent Survival	Number Embryos Malformed	Percent Malformed
UMD/WREC Control	1	24	96	2	8.3
	2	23	92	1	4.3
	3	24	96	2	4.3
	4	24	96	2	8.3
10	1	24	96	3	12.5
	2	23	92	1	4.3
18	1	23	92	2	8.7
	2	24	96	2	8.3
32	1	22	88	4	18.1
	2	23	92	6	26.1
56	1	21	84	6	28.6
	2	22	88	3	13.6
100	1	20	80	4	20.0
	2	21	84	7	33.3

TABLE A41-3. FETAX BEACH POINT BUFFERED GROUNDWATER TOXICITY  
TEST STATISTICAL ANALYSIS (TEST NO. 21) - PERCENT  
EMBRYO SURVIVAL AFTER 96 HOURS OF EXPOSURE

---

Data Transformation:

Arc sine square root

Chi-Square Test for Normality:

Calculated test statistic:	5.69
Alpha value:	0.01
Critical value:	13.28
Conclusion:	Fail to reject the null hypothesis that the data are normally distributed

Bartlett's Test for Homogeneity of Variances:

Calculated test statistic:	0.45
Alpha value:	0.01
Critical value:	13.28
Conclusion:	Fail to reject the null hypothesis that the variances are homogenous

ANOVA:

Calculated test statistic:	9.00
Alpha value:	0.05
Critical value:	3.69
Conclusion:	Reject the null hypothesis that all groups are equal

Bonferroni's T-test:

Calculated test statistic:	See Table A41-4
Alpha value:	0.05
Critical value:	2.90
Conclusion:	Reject the null hypothesis that all groups are equal

---

TABLE A41-4. FETAX BEACH POINT BUFFERED GROUNDWATER TOXICITY  
STATISTICAL ANALYSIS (TEST NO. 2) - RESULTS OF  
BONFERRONI'S T-TEST ON EMBRYO MORTALITY AFTER 96  
HOURS OF EXPOSURE

Conc (% by Vol)	No. of Reps	Mean Embryo Survival (%) <sub>a</sub>	T Statistic	Significance
UMD/WREC Control	4	95.0		
10	2	94.0	0.55	
18	2	94.0	0.55	
32	2	90.0	2.52	
56	2	86.0	4.13	*
100	2	82.0	5.55	*

<sub>a</sub> Values given are actual percent mean surviving embryos rather than arc sine square root transformed means which were used in the statistical analysis.

\* Significantly different at Alpha = 0.05 (Bonferroni's critical value = 2.90)

TABLE A41-5. FETAX BEACH POINT BUFFERED GROUNDWATER TOXICITY  
TEST STATISTICAL ANALYSIS (TEST NO. 2) - PERCENT  
EMBRYO MALFORMATIONS AFTER 96 HOURS OF EXPOSURE<sup>a</sup>

---

Data Transformation:

Arc sine square root

Chi-Square Test for Normality:

Calculated test statistic:	10.66
Alpha value:	0.01
Critical Value:	13.28
Conclusion:	Fail to reject the null hypothesis that the data are normally distributed

Bartlett's Test for Homogeneity of Variances:

Calculated test statistic:	5.85
Alpha value:	0.01
Critical value:	11.34
Conclusion:	Fail to reject the null hypothesis that the variances are homogenous

ANOVA:

Calculated test statistic:	6.50
Alpha value:	0.05
Critical value:	4.76
Conclusion:	Reject the null hypothesis that all groups are equal

Bonferroni's T-Test:

Calculated test statistic:	See Table A41-6
Alpha value:	0.05
Critical value:	2.75
Conclusion:	Reject the null hypothesis that all groups are equal

---

<sup>a</sup> The 56% and 100% buffered Beach Point groundwater treatment was not included in the statistical analyses because all concentrations above the NOEC for survival are excluded from the hypothesis test for malformation effects.

TABLE A41-6. FETAX BEACH POINT BUFFERED GROUNDWATER TOXICITY  
STATISTICAL ANALYSIS (TEST NO. 2) - RESULTS OF  
BONFERRONI'S T-TEST ON EMBRYO MALFORMATIONS AFTER  
96 HOURS OF EXPOSURE

Conc (% by Vol)	No. of Reps	Mean Normal Embryos (%) <sup>a</sup>	T Statistic	Significance
UMD/WREC Control	4	93.0		
10	2	91.5	0.63	
18	2	91.5	0.83	
32	2	78.0	4.33	*

<sup>a</sup> Values given are actual percent mean normal embryos rather than arc sine square root transformed means which were used in the statistical analysis.

\* Significantly different at alpha = 0.05 (Bonferroni's critical value = 2.75).

TABLE A41-7. FETAX BEACH POINT BUFFERED GROUNDWATER TOXICITY  
TEST DATA (TEST NO. 2) - TYPE AND NUMBER OF  
MALFORMED EMBRYOS AFTER 96 HOURS OF EXPOSURE

Malformation	Test Concentrations (% Groundwater by Volume)									
	0				10		18		32	
	<u>Rep</u>				<u>Rep</u>		<u>Rep</u>		<u>Rep</u>	
	1	2	3	4	1	2	1	2	1	2
Severe					1		1			
Gut, coiling									3	3
Edema:									3	2
Multiple	2	1	1		1		1	1	1	3
Cardiac									3	1
Abdominal						1		1		
Facial										
Cephalic										
Blisters										
Tail										
Notochord		1	1	1		1				
Fin										
Face										2
Eye										
Brain										
Hemorrhage										
Cardiac										
Other										

## APPENDIX 42

FROG EMBRYO TERATOGENESIS ASSAY - Xenopus (FETAX)  
CONDUCTED ON BEACH POINT RAW (pH  $\approx$ 4)  
GROUNDWATER (WELL 33B)  
(TEST NO. 3)

Test Method:	ASTM Designation E 1439-91 ASTM (1991)
Type of Test:	Static renewal (every 24 h)
Date:	August 26-30, 1993
Investigator:	S. D. Turley
Laboratory:	UMD/WREC
Groundwater:	
Source:	APG-EA Beach Point Well 33B
Chemical Characteristics:	See Appendix 48
Test Medium:	
Source:	FETAX solution
pH characteristics:	See Table A42-1
Test Organism:	
Scientific Name:	<u>Xenopus laevis</u>
Age at Start of Test:	Stage 8 blastula to stage 11 gastrulae
Source:	UMD/WREC culture
Experimental Chambers:	
Material:	Glass petri dishes
Test Solution Volume:	10 mL
No. Organisms/Replicate:	25
No. Organisms/Treatment:	Control: 100 Groundwater: 50
Loading:	n/a
Lighting:	Fluorescent; 60-85 foot candles
Aeration:	Prior to renewals



Endpoints:

Mortality; malformation

Test Temperature:

24 ± 0.2 °C

---

Results:

Mortality:

The raw groundwater did not affect embryo survival. The data are summarized in Tables A42-2 and A42-3.

Malformations:

Significant ( $\alpha = 0.05$ ) embryo malformations occurred at all concentrations down to 18% raw groundwater by volume (see Tables A42-2, A42-4, and A42-5). The NOEC and LOEC for the embryos, based on increased numbers of malformations, are as follows:

NOEC = 10% raw groundwater by volume.

LOEC = 18% raw groundwater by volume.

The types of malformed embryos are given in Table A42-6.

TABLE A42-1. SUMMARY OF THE BEACH POINT RAW GROUNDWATER  
BIOASSAY pH (STANDARD UNITS) DATA FOR FETAX (TEST  
NO. 3)

	<u>Test Concentrations (Percent Groundwater by Volume)</u>					
	0	10	18	32	56	100
<u>Day 0</u>						
0 H	7.70	7.51	7.21	6.93	6.32	3.97
<u>Day 1</u>						
0 H	7.62	7.38	7.09	6.77	6.28	4.07
<u>Day 2</u>						
0 H	7.59	7.26	7.17	7.00	6.33	4.02
<u>Day 3</u>						
0 H	7.65	7.32	7.11	6.69	6.07	3.95
<u>Day 4</u>						
24 H	7.51	7.20	7.01	6.58	6.01	4.01

TABLE A42-2. FETAX BEACH POINT RAW GROUNDWATER TOXICITY TEST  
DATA (TEST NO. 3) - PERCENT EMBRYO SURVIVAL AND  
MALFORMATIONS AFTER 96 HOURS OF EXPOSURE

Conc (% by Vol)	Rep	Number Embryos Alive	Percent Survival	Number Embryos Malformed	Percent Malformed
UMD/WREC Control	1	25	100	1	4.0
	2	24	96	2	8.3
	3	24	96	0	0.0
	4	24	96	1	4.2
APG-EA Control	1	24	96	2	8.3
	2	25	100	1	4.0
10	1	24	96	2	8.3
	2	23	92	2	8.7
18	1	23	92	3	13.0
	2	25	100	3	12.0
32	1	23	92	3	13.0
	2	24	96	4	16.7
56	1	25	100	4	16.0
	2	22	88	4	18.2
100	1	24	96	9	37.5
	2	22	88	10	45.5

TABLE A42-3. FETAX BEACH POINT RAW GROUNDWATER TOXICITY TEST  
STATISTICAL ANALYSIS (TEST NO. 3) - PERCENT EMBRYO  
SURVIVAL AFTER 96 HOURS OF EXPOSURE

---

Data Transformation:

Arc sine square root

Chi-Square Test for Normality:

Calculated test statistic:	7.43
Alpha value:	0.01
Critical value:	13.28
Conclusion:	Fail to reject the null hypothesis that the data are normally distributed

Bartlett's Test for Homogeneity of Variances:

Calculated test statistic:	2.74
Alpha value:	0.01
Critical value:	16.81
Conclusion:	Fail to reject the null hypothesis that the variances are homogenous

ANOVA:

Calculated test statistic:	0.44
Alpha value:	0.05
Critical value:	3.37
Conclusion:	Fail to reject the null hypothesis that all groups are equal

---

TABLE A42-4. FETAX BEACH POINT RAW GROUNDWATER TOXICITY TEST  
STATISTICAL ANALYSIS (TEST NO. 3) - PERCENT EMBRYO  
MALFORMATIONS AFTER 96 HOURS OF EXPOSURE

---

Data Transformation:

Arc sine square root

Chi-Square Test for Normality:

Calculated test statistic:	9.96
Alpha value:	0.01
Critical Value:	13.28
Conclusion:	Fail to reject the null hypothesis that the data are normally distributed

Bartlett's Test for Homogeneity of Variances:

Calculated test statistic:	7.46
Alpha value:	0.01
Critical value:	16.81
Conclusion:	Fail to reject the null hypothesis that the variances are homogenous

ANOVA:

Calculated test statistic:	21.00
Alpha value:	0.05
Critical value:	3.37
Conclusion:	Reject the null hypothesis that all groups are equal

Bonferroni's T-test:

Calculated test statistic:	See Table A42-5
Alpha value:	0.05
Critical value:	2.94
Conclusion:	Reject the null hypothesis that all groups are equal

---

TABLE A42-5. FETAX BEACH POINT RAW GROUNDWATER TOXICITY TEST  
STATISTICAL ANALYSIS (TEST NO. 3) - RESULTS OF  
BONFERRONI'S T-TEST ON EMBRYO MALFORMATIONS AFTER  
96 HOURS OF EXPOSURE

Conc (% by Vol)	No. of Reps	Mean Normal Embryos (%) <sup>a</sup>	T Statistic	Significance
UMD/WREC Control	4	95.9		
APG-EA	2	93.9	0.99	
10	2	91.5	2.02	
18	2	87.5	3.40	*
32	2	85.1	4.11	*
56	2	83.0	4.77	*
100	2	58.7	10.53	*

<sup>a</sup> Values given are actual percent mean normal embryos rather than arc sine square root transformed means which were used in the statistical analysis.

\* Significantly different at alpha = 0.05 (Bonferroni's critical value = 2.94).

TABLE A42-6. FETAX BEACH POINT RAW GROUNDWATER TOXICITY TEST DATA (TEST NO. 3) - TYPE AND NUMBER OF MALFORMED EMBRYOS AFTER 96 HOURS OF EXPOSURE.

Malformation	<u>Test Concentrations (% Groundwater by Volume)</u>							
	UMD <sup>a</sup>				APG <sup>b</sup>			
	<u>Rep</u>				<u>Rep</u>			
	1	2	3	4	1	2	1	2
Severe								
Gut, coiling	1		1		2		1	
Edema:								
Multiple		2			1	1	2	1
Cardiac								
Abdominal							1	1
Facial								
Cephalic								
Blisters								
Tail								
Notochord								
Fin								
Face						1		1
Eye								
Brain								
Hemorrhage								
Cardiac								
Other								

<sup>a</sup> UMD/WREC control.

<sup>b</sup> APG-EA control.

## APPENDIX 43

### FROG EMBRYO TERATOGENESIS ASSAY - Xenopus (FETAX) CONDUCTED ON BEACH POINT BUFFERED (pH $\approx$ 7) GROUNDWATER (WELL 33B) (TEST NO. 3)

Test Method:	ASTM Designation E 1439-91 ASTM (1991)
Type of Test:	Static renewal (every 24 h)
Date:	August 26-30, 1993
Investigator:	S. D. Turley
Laboratory:	UMD/WREC
Groundwater:	
Source:	APG-EA Beach Point Well 33B
Chemical Characteristics:	See Appendix 48
Test Medium:	
Source:	FETAX solution
pH characteristics:	See Table A43-1
Test Organism:	
Scientific Name:	<u>Xenopus laevis</u>
Age at Start of Test:	Stage 8 blastula to stage 11 gastrulae
Source:	UMD/WREC culture
Experimental Chambers:	
Material:	Glass petri dishes
Test Solution Volume:	10 mL
No. Organisms/Replicate:	25
No. Organisms/Treatment:	Groundwater: 50 Control: 100
Loading:	n/a
Lighting:	Fluorescent; 60-85 foot candles
Aeration:	Prior to renewals



pH Buffer:	10 N NaOH
Endpoints:	Mortality; malformations
Test Temperature:	24 ± 0.2 °C

---

#### Results:

##### Mortality:

The buffered groundwater did not affect embryo survival.  
The data are summarized in Tables A43-2 and A43-3.

##### Malformations:

Significant ( $\alpha = 0.05$ ) embryo malformations occurred at all concentrations down to 32% buffered groundwater by volume (see Tables A43-2, A43-4, and A43-5). The NOEC and LOEC for the embryos, based on increased numbers of malformations, are as follows:

NOEC = 18% buffered groundwater by volume.

LOEC = 32% buffered groundwater by volume.

The types of malformed embryos are given in Table A43-6.

TABLE A43-1. SUMMARY OF THE BEACH POINT BUFFERED GROUNDWATER  
BIOASSAY pH (STANDARD UNITS) DATA FOR FETAX (TEST  
NO. 3)

	<u>Test Concentrations (Percent Groundwater by Volume)</u>					
	0	10	18	32	56	100
<u>Day 0</u>						
0 H	7.70	7.48	7.41	7.38	7.30	7.25
<u>Day 1</u>						
0 H	7.62	7.58	7.51	7.37	7.33	7.30
<u>Day 2</u>						
0 H	7.59	7.63	7.55	7.43	7.37	7.57
<u>Day 3</u>						
0 H	7.65	7.50	7.44	7.41	7.33	7.21
<u>Day 4</u>						
24 H	7.50	7.36	7.30	7.23	7.17	7.09

TABLE A43-2. FETAX BEACH POINT BUFFERED GROUNDWATER TOXICITY  
TEST DATA (TEST NO. 3) - PERCENT EMBRYO SURVIVAL  
AND MALFORMATIONS AFTER 96 HOURS OF EXPOSURE

Conc (% by Vol)	Rep	Number Embryos Alive	Percent Survival	Number Embryos Malformed	Percent Malformed
UMD/WREC Control	1	25	100	1	4.0
	2	24	96	2	8.3
	3	24	96	0	0.0
	4	24	96	1	4.2
10	1	24	96	1	4.2
	2	25	100	2	8.0
18	1	24	96	2	8.3
	2	23	92	3	13.0
32	1	24	96	3	12.5
	2	23	92	3	13.0
56	1	24	96	4	16.7
	2	25	100	4	16.0
100	1	24	96	5	20.8
	2	23	92	7	30.4

TABLE A43-3. FETAX BEACH POINT BUFFERED GROUNDWATER TOXICITY  
TEST STATISTICAL ANALYSIS (TEST NO. 3) - PERCENT  
EMBRYO SURVIVAL AFTER 96 HOURS OF EXPOSURE

---

Data Transformation:

Arc sine square root

Chi-Square Test for Normality:

Calculated test statistic:	5.69
Alpha value:	0.01
Critical value:	13.28
Conclusion:	Fail to reject the null hypothesis that the data are normally distributed

Bartlett's Test for Homogeneity of Variance:

Calculated test statistic:	0.12
Alpha value:	0.01
Critical value:	15.09
Conclusion:	Fail to reject the null hypothesis that all groups are equal

ANOVA:

Calculated test statistic:	1.33
Alpha value:	0.05
Critical value:	3.69
Conclusion:	Fail to reject the null hypothesis that all groups are equal

---

TABLE A43-4. FETAX BEACH POINT BUFFERED GROUNDWATER TOXICITY  
TEST STATISTICAL ANALYSIS (TEST NO. 3) - PERCENT  
EMBRYO MALFORMATIONS AFTER 96 HOURS OF EXPOSURE

---

Data Transformation:

Arc sine square root

Chi-Square Test for Normality:

Calculated test statistic:	8.00
Alpha value:	0.01
Critical Value:	13.28
Conclusion:	Fail to reject the null hypothesis that the data are normally distributed

Bartlett's Test for Homogeneity of Variances:

Calculated test statistic:	7.80
Alpha value:	0.01
Critical value:	15.09
Conclusion:	Fail to reject the null hypothesis that the variances are homogenous

ANOVA:

Calculated test statistic:	9.00
Alpha value:	0.05
Critical value:	3.69
Conclusion:	Reject the null hypothesis that all groups are equal

Bonferroni's T-Test:

Calculated test statistic:	See Table A43-5
Alpha value:	0.05
Critical value:	2.90
Conclusion:	Reject the null hypothesis that all groups are equal

---

TABLE A43-5. FETAX BEACH POINT BUFFERED GROUNDWATER TOXICITY  
TEST STATISTICAL ANALYSIS (TEST NO. 3) - RESULTS OF  
BONFERRONI'S T-TEST ON EMBRYO MALFORMATIONS AFTER  
96 HOURS OF EXPOSURE

Conc (% by Vol)	No. of Reps	Mean Normal Embryos (%) <sup>a</sup>	T Statistic	Significance
UMD/WREC Control	4	95.9		
10	2	93.9	0.85	
18	2	89.4	2.38	
32	2	87.2	3.01	*
56	2	83.7	3.95	*
100	2	74.5	6.00	*

<sup>a</sup> Values given are actual percent mean normal embryos rather than arc sine square root transformed means which were used in the statistical analysis.

\* Significantly different at alpha = 0.05 (Bonferroni's critical value = 2.90).

TABLE A43-6. FETAX BEACH POINT BUFFERED GROUNDWATER TOXICITY  
TEST DATA (TEST NO. 3) - TYPE AND NUMBER OF  
MALFORMED EMBRYOS AFTER 96 HOURS OF EXPOSURE

Malformation	Test Concentrations (% Groundwater by Volume)													
	0				10		18		32		56		100	
	<u>Rep</u>				<u>Rep</u>		<u>Rep</u>		<u>Rep</u>		<u>Rep</u>		<u>Rep</u>	
	1	2	3	4	1	2	1	2	1	2	1	2	1	2
<hr/>														
Severe														
Gut, coiling	1			1			1	1	2	1	1	1	3	1
Edema:														
Multiple		2					1	1	2		2		2	3
Cardiac														
Abdominal					1		1		1		3	1		2
Facial														
Cephalic														
Blisters														
Tail														
Notochord						1								
Fin														
Face						1								1
Eye														
Brain														
Hemorrhage														
Cardiac														
Other														

## APPENDIX 44

FROG EMBRYO TERATOGENESIS ASSAY - Xenopus (FETAX)  
CONDUCTED ON BEACH POINT RAW (pH  $\approx$ 4)  
GROUNDWATER (WELL 33B)  
(TEST NO. 4)

Test Method:	ASTM Designation E 1439-91 (ASTM, 1991)
Type of Test:	Static renewal (every 24 h)
Date:	December 3 - 7, 1993
Investigator:	S. D. Turley
Laboratory:	UMD/WREC
Groundwater:	
Source:	APG-EA Beach Point Well 33B
Chemical Characteristics:	See Appendix 48
Test Medium:	
Source:	FETAX solution
pH characteristics:	See Table A44-1
Test Organism:	
Scientific Name:	<u>Xenopus laevis</u>
Age at Start of Test:	Stage 8 blastula to stage 11 gastrulae
Source:	UMD/WREC culture
Experimental Chambers:	
Material:	Glass petri dishes
Test Solution Volume:	10 mL
No. Organisms/Replicate:	25
No. Organisms/Treatment:	Control: 100 Groundwater: 50
Loading:	n/a
Lighting:	Fluorescent; 60-85 foot candles
Aeration:	Prior to renewals



Endpoints:

Mortality; malformation

Test Temperature:

24 ± 0.2 °C

---

Results:

Mortality:

Significant ( $\alpha = 0.05$ ) mortality occurred in frog embryos exposed for 96 h to 100% Beach Point raw groundwater. 100% Beach Point raw groundwater killed 26% of the frog embryos; thus, a 96-h LC50 could not be obtained. The data are summarized in Tables A44-2, A44-3, and A44-4.

Malformations:

Significant ( $\alpha = 0.05$ ) embryo malformations occurred at a concentration of 56% raw groundwater by volume (see Tables A44-2, A44-4, and A44-5). The NOEC and LOEC for the embryos, based on increased numbers of malformations, are as follows:

NOEC = 32% raw groundwater by volume.

LOEC = 56% raw groundwater by volume.

The types of malformed embryos are given in Table A44-6.

TABLE A44-1. SUMMARY OF THE BEACH POINT RAW GROUNDWATER  
BIOASSAY pH (STANDARD UNITS) DATA FOR FETAX (TEST  
NO. 4)

	<u>Test Concentrations (Percent Groundwater by Volume)</u>					
	0	10	18	32	56	100
<u>Day 0</u>						
0 H	7.51	7.33	7.18	6.99	6.54	3.91
<u>Day 1</u>						
0 H	7.50	7.40	7.23	7.06	6.61	3.99
<u>Day 2</u>						
0 H	7.44	7.19	7.11	6.91	6.44	3.87
<u>Day 3</u>						
0 H	7.49	7.27	7.14	7.00	6.52	3.88

TABLE A44-2. FETAX BEACH POINT RAW GROUNDWATER TOXICITY TEST  
DATA (TEST NO. 4) - PERCENT EMBRYO SURVIVAL AND  
MALFORMATIONS AFTER 96 HOURS OF EXPOSURE

Conc (% by Vol)	Rep	Number Embryos Alive	Percent Survival	Number Embryos Malformed	Percent Malformed
UMD/WREC Control	1	25	100	2	8.0
	2	24	96	2	8.3
	3	25	100	1	4.0
	4	24	96	1	4.2
APG-EA Diluent Water	1	23	92	2	8.7
	2	25	100	2	8.0
10	1	25	100	1	4.0
	2	24	96	2	8.3
18	1	24	96	1	4.2
	2	25	100	2	8.0
32	1	23	92	3	13.0
	2	25	100	2	8.0
56	1	22	88	4	18.2
	2	23	92	4	17.4
100	1	18	72	9	50.0
	2	19	76	10	52.6

TABLE A44-3. FETAX BEACH POINT RAW GROUNDWATER TOXICITY TEST  
STATISTICAL ANALYSIS (TEST NO. 4) - PERCENT EMBRYO  
SURVIVAL AFTER 96 HOURS OF EXPOSURE

---

Data Transformation:

Arc sine square root

Shapiro-Wilk's Test for Normality:

Calculated test statistic:	0.91
Alpha value:	0.01
Critical value:	0.84
Conclusion:	Fail to reject the null hypothesis that the data are normally distributed

Bartlett's Test for Homogeneity of Variances:

Calculated test statistic:	2.92
Alpha value:	0.01
Critical value:	16.59
Conclusion:	Fail to reject the null hypothesis that the variances are homogenous

ANOVA:

Calculated test statistic:	31.14
Alpha value:	0.05
Critical value:	3.37
Conclusion:	Reject the null hypothesis that all groups are equal

Bonferroni T-Test:

Calculated test statistic:	See Table A44-4
Alpha value:	0.05
Critical value:	2.94
Conclusion:	Reject the null hypothesis that all groups are equal

---

TABLE A44-4. FETAX BEACH POINT RAW GROUNDWATER TOXICITY TEST  
STATISTICAL ANALYSIS (TEST NO. 4) - RESULT'S OF  
BONFERRONI'S T-TEST ON EMBRYO MORTALITY AFTER 96  
HOURS OF EXPOSURE

Conc (% by Vol)	No. of Reps	Mean Embryo Mortality (%) <sup>a</sup>	T-Statistic	Significance
UMD/WREC Control	4	2.0		
APG-EA Diluent Water	2	4.0	0.589	
10	2	2.0	0.000	
18	2	2.0	0.000	
32	2	4.0	0.589	
56	2	10.0	2.339	
100	2	26.0	12.218	*

<sup>a</sup> Values given are actual percent mean mortality rather than arc  
sine square root transformed means which were used in the  
statistical analysis.

\* Significantly different at alpha= 0.05 (Bonferroni critical  
value = 2.94).

TABLE A44-5. FETAX BEACH POINT RAW GROUNDWATER TOXICITY TEST  
STATISTICAL ANALYSIS (TEST NO. 4) - PERCENT EMBRYO  
MALFORMATIONS AFTER 96 HOURS OF EXPOSURE

---

Data Transformation:

Arc sine square root

Shapiro-Wilk's Test for Normality:

Calculated test statistic:	0.84
Alpha value:	0.01
Critical Value:	0.83
Conclusion:	Fail to reject the null hypothesis that the data are normally distributed

Bartlett's Test for Homogeneity of Variances:

Calculated test statistic:	5.69
Alpha value:	0.01
Critical value:	15.09
Conclusion:	Fail to reject the null hypothesis that the variances are homogenous

ANOVA:

Calculated test statistic:	6.00
Alpha value:	0.05
Critical value:	3.69
Conclusion:	Reject the null hypothesis that all groups are equal

Bonferroni's T-test:

Calculated test statistic:	See Table A44-5
Alpha value:	0.05
Critical value:	2.90
Conclusion:	Reject the null hypothesis that all groups are equal

---

TABLE A44-6. FETAX BEACH POINT RAW GROUNDWATER TOXICITY TEST DATA (TEST NO. 4) - TYPE AND NUMBER OF MALFORMED EMBRYOS AFTER 96 HOURS OF EXPOSURE.

Malformation	Test Concentrations (% Groundwater by Volume)															
	UMD <sup>a</sup>				APG <sup>b</sup>		10		18		32		56		100	
	<u>Rep</u>				<u>Rep</u>		<u>Rep</u>		<u>Rep</u>		<u>Rep</u>		<u>Rep</u>		<u>Rep</u>	
	1	2	3	4	1	2	1	2	1	2	1	2	1	2	1	2
Severe													1		1	
Gut, coiling	1	1			2	1	1	1					1		2	2
Edema:																
Multiple	1		1	1	1		1		1	1	1		2	1	4	5
Cardiac																1
Abdominal											1	2	1	2		1
Facial																
Cephalic																
Blisters																
Tail																
Notochord		1							1		1				1	1
Fin																
Face																1
Eye																
Brain																
Hemorrhage																
Cardiac																
Other																

<sup>a</sup> UMD/WREC control.

<sup>b</sup> APG-EA diluent water.

## APPENDIX 45

### FROG EMBRYO TERATOGENESIS ASSAY - Xenopus (FETAX) CONDUCTED ON BEACH POINT BUFFERED (pH $\approx$ 7) GROUNDWATER (WELL 33B) (TEST NO. 4)

Test Method:	ASTM Designation E 1439-91 (ASTM, 1991)
Type of Test:	Static renewal (every 24 h)
Date:	December 3 - 7, 1993
Investigator:	S. D. Turley
Laboratory:	UMD/WREC
Groundwater:	
Source:	APG-EA Beach Point Well 33B
Chemical Characteristics:	See Appendix 48
Test Medium:	
Source:	FETAX solution
pH characteristics:	See Table A45-1
Test Organism:	
Scientific Name:	<u>Xenopus laevis</u>
Age at Start of Test:	Stage 8 blastula to stage 11 gastrulae
Source:	UMD/WREC culture
Experimental Chambers:	
Material:	Glass petri dishes
Test Solution Volume:	10 mL
No. Organisms/Replicate:	25
No. Organisms/Treatment:	Groundwater: 50 Control: 100
Loading:	n/a
Lighting:	Fluorescent; 60-85 foot candles
Aeration:	Prior to renewals



pH Buffer:	10 N NaOH
Endpoints:	Mortality; malformations
Test Temperature:	24 ± 0.2 °C

---

Results:

Mortality:

The 100% Beach Point buffered groundwater caused a significant ( $\alpha = 0.05$ ) reduction in embryo survival. 100% Beach Point buffered groundwater only killed 13% of the frog embryos; thus, a 96-h LC50 could not be obtained. The data are summarized in Tables A45-2, A45-3, and A45-4.

Malformations:

Significant ( $\alpha = 0.05$ ) embryo malformations occurred at all treatments down to 32% buffered groundwater by volume (see Tables A45-2, A45-5, and A45-6). The NOEC and LOEC for the embryos, based on increased numbers of malformations, are as follows:

NOEC = 18% buffered groundwater by volume.

LOEC = 32% buffered groundwater by volume.

The types of malformed embryos are given in Table A45-7.

TABLE A45-1. SUMMARY OF THE BEACH POINT BUFFERED GROUNDWATER  
BIOASSAY pH (STANDARD UNITS) DATA FOR FETAX (TEST  
NO. 4)

	<u>Test Concentrations (Percent Groundwater by Volume)</u>					
	0	10	18	32	56	100
<u>Day 0</u>						
0 H	7.51	7.40	7.28	7.32	7.32	7.40
<u>Day 1</u>						
0 H	7.50	7.44	7.33	7.28	7.19	7.11
<u>Day 2</u>						
0 H	7.44	7.40	7.30	7.26	7.17	7.10
<u>Day 3</u>						
0 H	7.49	7.51	7.50	7.40	7.43	7.39
<u>Day 4</u>						
24 H	7.58	7.47	7.40	7.35	7.30	7.27

TABLE A45-2. FETAX BEACH POINT BUFFERED GROUNDWATER TOXICITY  
TEST DATA (TEST NO. 4) - PERCENT EMBRYO SURVIVAL  
AND MALFORMATIONS AFTER 96 HOURS OF EXPOSURE

Conc (% by Vol)	Rep	Number Embryos Alive	Percent Survival	Number Embryos Malformed	Percent Malformed
UMD/WREC Control	1	25	100	2	8.0
	2	24	96	2	8.3
	3	25	100	1	4.0
	4	24	96	1	4.2
10	1	24	96	2	8.3
	2	25	100	1	4.0
18	1	23	92	2	8.7
	2	25	100	2	8.0
32	1	24	96	3	12.5
	2	23	92	4	17.4
56	1	24	96	5	20.8
	2	22	88	4	18.1
100	1	20	80	7	20.8
	2	23	92	7	30.4

TABLE A45-3. FETAX BEACH POINT BUFFERED GROUNDWATER TOXICITY  
TEST STATISTICAL ANALYSIS (TEST NO. 4) - PERCENT  
EMBRYO SURVIVAL AFTER 96 HOURS OF EXPOSURE

---

Data Transformation:

Arc sine square root

Shapiro-Wilk's Test for Normality:

Calculated test statistic:	0.86
Alpha value:	0.01
Critical value:	0.83
Conclusion:	Fail to reject the null hypothesis that the data are normally distributed

Bartlett's Test for Homogeneity of Variance:

Calculated test statistic:	1.32
Alpha value:	0.01
Critical value:	15.09
Conclusion:	Fail to reject the null hypothesis that all groups are equal

ANOVA:

Calculated test statistic:	2.13
Alpha value:	0.05
Critical value:	3.69
Conclusion:	Reject the null hypothesis that all groups are equal

Bonferroni's T-Test

Calculated test statistic:	See Table A45-4
Alpha value:	0.01
Critical value:	2.90
Conclusion:	Reject the null hypothesis that all groups are equal

---

TABLE A45-4. FETAX BEACH POINT BUFFERED GROUNDWATER TOXICITY  
TEST STATISTICAL ANALYSIS (TEST NO. 4) - RESULT'S  
OF BONFERRONI'S T-TEST ON EMBRYO MORTALITY AFTER 96  
HOURS OF EXPOSURE

Conc (% by Vol)	No. of Reps	Mean Embryo Mortality (%) <sup>a</sup>	T-Statistic	Significance
UMD/WREC Control	4	2.0		
10	2	2.0	0.000	
18	2	4.0	0.551	
32	2	6.0	1.204	
56	2	8.0	1.637	
100	2	14.0	2.898	*

<sup>a</sup> Values given are actual percent mean mortality rather than arc sine square root transformed means which were used in the statistical analysis.

\* Significantly different at alpha = 0.05 (Bonferroni's critical value = 2.90).

TABLE A45-5. FETAX BEACH POINT BUFFERED GROUNDWATER TOXICITY  
TEST STATISTICAL ANALYSIS (TEST NO. 4) - PERCENT  
EMBRYO MALFORMATIONS AFTER 96 HOURS OF EXPOSURE

---

Data Transformation:

Arc sine square root

Chi-Square Test for Normality:

Calculated test statistic:	6.09
Alpha value:	0.01
Critical Value:	13.28
Conclusion:	Fail to reject the null hypothesis that the data are normally distributed

Bartlett's Test for Homogeneity of Variances:

Calculated test statistic:	3.39
Alpha value:	0.01
Critical value:	13.28
Conclusion:	Fail to reject the null hypothesis that the variances are homogenous

ANOVA:

Calculated test statistic:	9.00
Alpha value:	0.05
Critical value:	4.12
Conclusion:	Reject the null hypothesis that all groups are equal

Bonferroni's T-Test:

Calculated test statistic:	See Table A45-5
Alpha value:	0.05
Critical value:	2.84
Conclusion:	Reject the null hypothesis that all groups are equal

---

TABLE A45-6. FETAX BEACH POINT BUFFERED GROUNDWATER TOXICITY TEST STATISTICAL ANALYSIS (TEST NO. 4) - RESULTS OF BONFERRONI'S T-TEST ON EMBRYO MALFORMATIONS AFTER 96 HOURS OF EXPOSURE<sup>a</sup>

Conc (% by Vol)	No. of Reps	Mean Normal Embryos (%) <sup>b</sup>	T Statistic	Significance
UMD/WREC Control	4	92.9		
10	2	93.9	-0.516	
18	2	91.7	0.679	
32	2	85.1	3.332	*
56	2	80.6	4.899	*

<sup>a</sup> The 100% Beach Point raw groundwater treatment was not included in the statistical analyses because all concentrations above the NOEC for survival are excluded from the hypothesis test for malformations.

<sup>b</sup> Values given are actual percent mean normal embryos rather than arc sine square root transformed means which were used in the statistical analysis.

\* Significantly different at alpha = 0.05 (Bonferroni's critical value = 2.84).

TABLE A45-7. FETAX BEACH POINT BUFFERED GROUNDWATER TOXICITY  
TEST DATA (TEST NO. 4) - TYPE AND NUMBER OF  
MALFORMED EMBRYOS AFTER 96 HOURS OF EXPOSURE

Malformation	Test Concentrations (% Groundwater by Volume)									
	0				10		18		32	
	<u>Rep</u>				<u>Rep</u>		<u>Rep</u>		<u>Rep</u>	
	1	2	3	4	1	2	1	2	1	2
Severe									1	
Gut, coiling	1	1			2		1			
Edema:										
Multiple	1		1	1	1		2	1	2	1
Cardiac										
Abdominal									1	2
Facial										
Cephalic										
Blisters										
Tail										
Notochord										
Fin										
Face										
Eye										
Brain										
Hemorrhage										
Cardiac										
Other										



APPENDIX 46

SIX-MONTH INTERIM AND NINE-MONTH FINAL JAPANESE MEDAKA  
CHRONIC HISTOPATHOLOGY GROWTH DATA

TABLE A46-1. SIX-MONTH INTERIM GROWTH DATA OF JAPANESE MEDAKA DURING THE CHRONIC HISTOPATHOLOGY EXPOSURE STUDY (SACRIFICED ON AUGUST 25, 1993; TEST DAY 182) - DILUENT WATER

Tank 1			Tank 2			Tank 3			Tank 4		
Fish No.	Wet Weight (mg)	Standard Length (mm)	Fish No.	Wet Weight (mg)	Standard Length (mm)	Fish No.	Wet Weight (mg)	Standard Length (mm)	Fish No.	Wet Weight (mg)	Standard Length (mm)
1	573	33	1	401	30	1	314	28	1	520	30
2	423	31	2	349	27	2	416	32	2	367	28
3	484	32	3	530	34	3	423	33	3	499	31
4	473	32	4	714	34	4	627	34	4	545	31
5	271	26	5	330	30	5	463	31	5	529	32
6	489	31	6	364	30	6	548	31	6	568	32
7	579	34	7	480	31	7	388	29	7	433	31
8	495	29	8	508	32	8	323	27	8	557	31
9	442	32	9	568	32	9	427	32	9	688	33
10	458	30	10	423	29	10	526	31	10	475	31
11	528	31	11	496	32	11	308	29	11	542	31
12	593	32	12	371	28	12	513	30	12	447	29
13	482	31	13	372	30	13	514	31	13	519	30
14	612	32	14	495	31	14	517	30	14	504	31
15	446	32	15	401	29	15	362	29	15	470	30
16	516	32	16	459	30	16	512	31	16	406	29
17	425	32	17	413	31	17	617	32	17	384	27
18	620	34	18	339	27	18	545	31	18	423	32
19	395	28	19	722	34	19	511	30	19	323	27
20	354	29	20	614	33	20	525	32	20	589	32
Mean	483	31		467	31		469	31		489	30
Min	271	26		330	27		308	27		323	27
Max	620	34		722	34		627	34		688	33
S.D.	86.1	1.9		113.3	2.1		92.5	1.7		83.8	1.6
N	20	20		20	20		20	20		20	20

TABLE A46-1. (CONTINUED) - 1% GROUNDWATER

Tank 5			Tank 6			Tank 7			Tank 8		
Fish No.	Wet Weight (mg)	Standard Length (mm)	Fish No.	Wet Weight (mg)	Standard Length (mm)	Fish No.	Wet Weight (mg)	Standard Length (mm)	Fish No.	Wet Weight (mg)	Standard Length (mm)
1	412	27	1	512	32	1	425	34	1	396	28
2	283	27	2	677	32	2	433	30	2	457	30
3	772	32	3	484	29	3	503	30	3	596	21
4	389	29	4	808	35	4	348	30	4	435	30
5	349	29	5	472	31	5	523	32	5	573	32
6	499	31	6	584	32	6	422	28	6	549	31
7	632	31	7	345	29	7	531	31	7	422	29
8	474	30	8	263	26	8	377	28	8	434	32
9	429	28	9	403	28	9	417	30	9	604	32
10	423	32	10	657	35	10	479	31	10	363	27
11	640	32	11	478	30	11	388	30	11	669	32
12	457	30	12	376	29	12	405	30	12	507	32
13	591	32	13	403	31	13	539	30	13	497	32
14	508	30	14	605	34	14	602	32	14	563	32
15	524	30	15	462	32	15	416	31	15	642	32
16	639	31	16	344	28	16	481	30	16	456	30
17	473	29	17	383	30	17	601	32	17	506	29
18	651	31	18	492	30	18	403	29	18	520	32
19	348	28	19	489	30	19	377	29	19	457	31
20	506	30	20	430	30	20	293	28	20	415	30
21	507	31									
Mean	500	30		483	31		448	30		503	30
Min	283	27		263	26		293	28		363	21
Max	772	32		808	35		602	34		669	32
S.D.	117.4	1.5		127.3	2.3		80.0	1.5		83.0	2.6
N	21	21		20	20		20	20		20	20

TABLE A46-1. (CONTINUED) - 10% GROUNDWATER

Tank 9			Tank 10			Tank 11			Tank 12		
Fish No.	Wet Weight (mg)	Standard Length (mm)	Fish No.	Wet Weight (mg)	Standard Length (mm)	Fish No.	Wet Weight (mg)	Standard Length (mm)	Fish No.	Wet Weight (mg)	Standard Length (mm)
1	467	30	1	607	31	1	364	31	1	565	32
2	610	32	2	478	30	2	418	31	2	586	30
3	545	32	3	446	30	3	478	32	3	609	32
4	392	31	4	493	31	4	560	32	4	427	31
5	591	33	5	397	30	5	423	30	5	510	31
6	450	31	6	565	32	6	718	34	6	430	32
7	490	31	7	564	32	7	294	27	7	462	31
8	583	31	8	532	31	8	291	29	8	461	30
9	599	32	9	437	30	9	416	28	9	573	31
10	555	31	10	510	31	10	555	31	10	466	31
11	411	29	11	418	30	11	548	33	11	325	27
12	586	31	12	419	30	12	451	28	12	469	32
13	587	31	13	593	33	13	680	33	13	387	31
14	303	27	14	493	31	14	576	30	14	712	34
15	476	29	15	480	31	15	536	33	15	444	30
16	541	31	16	338	28	16	578	32	16	380	29
17	496	31	17	640	33	17	296	28	17	427	31
18	400	31	18	471	32	18	505	31	18	392	31
19	573	32	19	548	33	19	444	32	19	437	29
20	659	33	20	420	29	20	320	29	20	302	29
Mean	516	31		492	31		473	31		468	31
Min	303	27		338	28		291	27		302	27
Max	659	33		640	33		718	34		712	34
S.D.	88.6	1.4		76.0	1.3		120.7	2.0		97.5	1.5
N	20	20		20	20		20	20		20	20

TABLE A46-2. JAPANESE MEDAKA BEACH POINT GROUNDWATER CHRONIC  
HISTOPATHOLOGY ASSAY STATISTICAL ANALYSIS - WET  
WEIGHT AFTER SIX MONTHS OF EXPOSURE

---

Data Transformation:

None

Kolmogorov-Smirnov Test for Normality:

Data were normally distributed (P = 0.127)

Levene Median Test for Homogeneity of Variances:

Variances were homogenous (P = 0.682)

General Linear Model Type III Test- Replicates within Treatment  
as the Error Term:

Source	DF	Sum of Squares	Mean Square	F Value	P > F
Treatment	2	4162.5043	2081.2521	0.25	0.781

---

Results:

No difference in wet weight occurred between the Japanese medaka exposed for six months to 10% groundwater by volume, 1% groundwater by volume, and diluent water.

TABLE A46-2. (CONTINUED) - STANDARD LENGTH AFTER SIX MONTHS OF EXPOSURE

---

Data Transformation:

None

Kolmogorov-Smirnov Test for Normality:

Data were not normally distributed ( $P < 0.001$ )

Kruskal Wallis One Way ANOVA on Ranks:

Group	N	Median	H	P
Control	80	31.0		
10%	80	30.0		
1%	81	30.0	4.042	0.133

---

Results:

No difference in standard length occurred between the Japanese medaka exposed for six months to 10% groundwater by volume, 1% groundwater by volume, and diluent water.

TABLE A46-3. NINE-MONTH FINAL GROWTH DATA OF JAPANESE MEDAKA DURING THE CHRONIC HISTOPATHOLGY EXPOSURE STUDY (SACRIFICED ON NOVEMBER 29, 1993; TEST DAY 278) - DILUENT WATER

Tank 1			Tank 2			Tank 3			Tank 4		
Fish No.	Wet Weight (mg)	Standard Length (mm)	Fish No.	Wet Weight (mg)	Standard Length (mm)	Fish No.	Wet Weight (mg)	Standard Length (mm)	Fish No.	Wet Weight (mg)	Standard Length (mm)
1	321	30	1	346	28	1	362	27	1	459	29
2	505	31	2	377	27	2	482	32	2	773	34
3	524	30	3	661	33	3	521	30	3	521	30
4	580	31	4	576	32	4	723	35	4	424	29
5	574	32	5	725	34	5	453	32	5	503	33
6	782	34	6	686	32	6	569	34	6	702	35
7	628	33	7	413	31	7	709	36	7	599	30
8	447	32	8	522	31	8	641	31	8	452	31
9	525	32	9	610	34	9	424	31	9	777	32
10	689	34	10	450	28	10	664	32	10	752	35
11	715	34	11	600	33	11	474	34	11	569	32
12	680	34	12	303	26	12	464	32	12	798	36
13	1044	37	13	592	33	13	365	29	13	393	29
14	610	32	14	366	27	14	372	30	14	692	36
15	736	32	15	429	31	15	647	32	15	309	25
16	456	32	16	668	34	16	536	34	16	459	30
17	586	32	17	699	32	17	547	32	17	476	31
18	507	31	18	470	31	18	587	33	18	473	31
19	656	32	19	797	34	19	626	32	19	477	31
20	628	32	20	724	35	20	902	36	20	679	34
21	385	30	21	741	34				21	646	32
22	481	32	22	806	36				22	496	30
23	593	32	23	459	31				23	553	32
24	796	33	24	693	34				24	804	34
			25	778	34				25	736	34

TABLE A46-3. (CONTINUED) - DILUENT WATER CONT

Tank 1			Tank 2			Tank 3			Tank 4		
Fish No.	Wet Weight (mg)	Standard Length (mm)	Fish No.	Wet Weight (mg)	Standard Length (mm)	Fish No.	Wet Weight (mg)	Standard Length (mm)	Fish No.	Wet Weight (mg)	Standard Length (mm)
			29	502	32				29	480	29
			30	315	26				30	439	32
			31	552	32				31	658	34
									32	480	30
									33	557	32
									34	465	32
									35	695	31
<hr/>											
Mean	602	32		573	32		553	32		565	32
Min	321	30		303	26		362	27		309	25
Max	1044	37		806	36		902	36		804	36
S.D.	148.9	1.5		149.4	2.6		134.6	2.2		129.4	2.3
N	24	24		31	31		20	20		35	35



TABLE A46-3. (CONTINUED) - 1% GROUNDWATER

Tank 5			Tank 6			Tank 7			Tank 8		
Fish No.	Wet Weight (mg)	Standard Length (mm)	Fish No.	Wet Weight (mg)	Standard Length (mm)	Fish No.	Wet Weight (mg)	Standard Length (mm)	Fish No.	Wet Weight (mg)	Standard Length (mm)
1	546	31	1	549	32	1	695	33	1	384	29
2	350	36	2	572	31	2	578	34	2	346	31
3	658	31	3	641	34	3	438	32	3	510	32
4	640	32	4	555	31	4	522	30	4	474	32
5	683	32	5	828	34	5	563	33	5	575	32
6	562	31	6	484	32	6	662	32	6	518	30
7	607	32	7	297	28	7	622	33	7	884	34
8	706	32	8	548	30	8	587	32	8	626	33
9	612	31	9	491	30	9	349	30	9	618	32
10	390	28	10	740	30	10	668	32	10	609	34
11	630	32	11	830	32	11	553	33	11	625	32
12	923	35	12	642	33	12	708	35	12	615	33
13	519	30	13	548	30	13	549	31	13	440	32
14	468	29	14	487	30	14	784	35	14	473	32
15	488	30	15	589	34	15	517	31	15	658	33
16	502	30	16	629	32	16	568	31	16	325	27
17	464	31	17	654	34	17	393	30	17	678	32
18	806	34	18	371	30	18	373	29	18	551	30
19	535	30	19	600	35	19	603	31	19	525	32
20	773	35	20	416	30	20	806	34	20	527	30
21	544	32	21	422	28	21	456	31	21	501	32
22	641	34	22	533	32	22	456	31	22	470	30
23	704	32	23	604	33	23	588	32	23	405	30
24	590	32	24	468	30	24	616	32	24	539	31
25	550	33	25	331	34	25	566	32	25	428	30

TABLE A46-3. (CONTINUED) - 1% GROUNDWATER CON'T

Tank 5				Tank 6				Tank 7				Tank 8			
Fish No.	Wet Weight (mg)	Standard Length (mm)		Fish No.	Wet Weight (mg)	Standard Length (mm)		Fish No.	Wet Weight (mg)	Standard Length (mm)		Fish No.	Wet Weight (mg)	Standard Length (mm)	
26	713	34		26	556	31		26	672	34		26	751	36	
27	700	32		27	514	32		27	715	35		27	549	32	
28	508	31		28	621	34		28	542	31		28	879	36	
29	361	30		29	751	34						29	467	31	
30	520	31		30	431	31						30	484	31	
31	467	29		31	498	30						31	603	30	
32	503	30		32	432	30						32	493	30	
				33	749	34						33	458	31	
				34	467	30						34	328	30	
												35	595	35	
												36	290	28	
												37	531	30	
<hr/>															
Mean	583	32		554	32			577	32			533	31		
Min	350	28		297	28			349	29			290	27		
Max	923	36		830	35			806	35			884	36		
S.D.	126.5	1.8		127.6	1.9			113.4	1.6			131.5	1.9		
N	32	32		34	34			28	28			37	37		

TABLE A46-3. (CONTINUED) - 10% GROUNDWATER

Tank 9				Tank 10				Tank 11				Tank 12			
Fish No.	Wet Weight (mg)	Standard Length (mm)		Fish No.	Wet Weight (mg)	Standard Length (mm)		Fish No.	Wet Weight (mg)	Standard Length (mm)		Fish No.	Wet Weight (mg)	Standard Length (mm)	
1	580	32		1	789	36		1	413	31		1	318	29	
2	762	34		2	378	29		2	543	32		2	379	30	
3	736	34		3	390	30		3	508	31		3	608	32	
4	483	31		4	760	36		4	687	35		4	616	32	
5	662	34		5	542	30		5	678	33		5	544	30	
6	782	34		6	451	31		6	757	33		6	489	32	
7	697	34		7	496	35		7	441	31		7	459	34	
8	692	35		8	687	36		8	547	31		8	450	30	
9	691	34		9	552	32		9	691	34		9	659	33	
10	648	30		10	728	36		10	478	31		10	442	30	
11	496	32		11	836	35		11	532	31		11	604	32	
12	655	34		12	458	31		12	393	31		12	582	35	
13	534	30		13	604	33		13	722	34		13	592	35	
14	606	34		14	502	30		14	551	33		14	731	35	
15	582	35		15	872	36		15	845	34		15	453	32	
16	626	34		16	625	32		16	461	31		16	665	36	
17	731	35		17	361	30		17	412	30		17	497	32	
18	691	36		18	682	34		18	535	30		18	347	27	
19	681	32		19	835	35		19	631	32		19	403	30	
20	526	32		20	366	30		20	604	32		20	594	33	
21	550	34		21	522	34		21	472	31		21	825	36	
22	558	32		22	606	34		22	619	34		22	615	33	
23	448	32		23	553	33		23	363	30		23	741	34	
24	777	37		24	432	30		24	462	30		24	468	28	
25	562	31		25	873	36		25	496	31		25	616	33	

TABLE A46-3. (CONTINUED) - 10% GROUNDWATER CONT

Tank 9			Tank 10			Tank 11			Tank 12		
Fish No.	Wet Weight (mg)	Standard Length (mm)	Fish No.	Wet Weight (mg)	Standard Length (mm)	Fish No.	Wet Weight (mg)	Standard Length (mm)	Fish No.	Wet Weight (mg)	Standard Length (mm)
26	690	34	26	775	34	26	690	35	26	560	31
27	828	36	27	651	35	27	403	30	27	557	31
28	469	33	28	743	35	28	368	26	28	531	32
29	356	30	29	498	33	29	522	32	29	706	26
30	610	32	30	853	34	30	438	30	30	463	31
31	661	34	31	693	33	31	642	33	31	689	34
32	685	35	32	428	30	32	608	34	32	388	31
33	406	34	33	560	30	33	437	30	33	704	35
34	471	29				34	585	32	34	508	34
35	671	34				35	766	34	35	474	30
						36	672	36	36	629	42
Mean	617	33		609	33		555	32		553	32
Min	356	29		361	29		363	26		318	26
Max	828	37		873	36		845	36		825	42
S.D.	111.8	1.9		158.4	2.3		123.0	1.9		118.7	2.9
N	35	35		33	33		36	36		36	36

TABLE A46-4. JAPANESE MEDAKA BEACH POINT GROUNDWATER CHRONIC HISTOPATHOLOGY ASSAY STATISTICAL ANALYSIS - WET WEIGHT AFTER NINE MONTHS OF EXPOSURE

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Data Transformation:

None

Kolmogorov-Smirnov Test for Normality:

Data were normally distributed ( $P = 0.119$ )

Levene Median Test for Homogeneity of Variances:

Variances were homogenous ( $P = 0.216$ )

General Linear Model Type III Test- Replicates within Treatment as the Error Term:

Source	DF	Sum of Squares	Mean Square	F Value	P > F
Treatment	2	31435.8821	15717.9411	0.68	0.530

---

Results:

No difference in wet weight occurred between the Japanese medaka exposed for nine months to 10% groundwater by volume, 1% groundwater by volume, and diluent water.

TABLE A46-4. (CONTINUED) - STANDARD LENGTH AFTER NINE MONTHS OF EXPOSURE

---

Data Transformation:

None

Kolmogorov-Smirnov Test for Normality:

Data were not normally distributed ( $P < 0.001$ )

Kruskal Wallis One Way ANOVA on Ranks:

Group	N	Median	H	P
Control	110	32.0		
10%	140	32.5		
1%	131	32.0	11.389	0.003

Dunn's Multiple Comparison Test:

Comparison	Difference of Rank	Q	P
10% vs. control	28.482	2.033	<0.05
1% vs. control	15.990		Not Tested

---

Results:

The Kruskal Wallis test indicates that a significant difference ( $\alpha = 0.003$ ) in standard length occurred between the Japanese medaka exposed for nine months to 10% groundwater by volume, 1% groundwater by volume, and diluent water. However, when Dunn's multiple comparison test is used to enumerate the difference between the control and each experimental treatment, no statistically significant difference ( $\alpha = 0.05$ ) occurs.

APPENDIX 47

SUMMARY OF THE SIX-MONTH INTERIM AND NINE-MONTH  
FINAL JAPANESE MEDAKA CHRONIC  
HISTOPATHOLOGY RESULTS

**EPL<sup>®</sup>**

EXPERIMENTAL PATHOLOGY LABORATORIES, INC.

U.S. ARMY BIOMEDICAL RESEARCH  
AND DEVELOPMENT LABORATORY  
TEST 401-001R  
EPL PROJECT NUMBER 406-027  
BEACH POINT GROUNDWATER STUDY WITH MEDAKA  
AMENDED PATHOLOGY REPORT  
VOLUME 1

Submitted by:

Experimental Pathology Laboratories, Inc.  
P.O. Box 474  
Herndon, VA 22070  
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Submitted to:

U.S. Army Biomedical Research  
and Development Laboratory  
Fort Detrick, MD 21702-5010

August 26, 1994



U.S. ARMY BIOMEDICAL RESEARCH AND DEVELOPMENT LABORATORY  
TEST 401-001R  
EPL PROJECT NUMBER 406-027

BEACH POINT GROUNDWATER STUDY WITH MEDAKA  
AMENDED PATHOLOGY SUMMARY

A histopathological evaluation was performed on tissues from fish of the species *Oryzias latipes* (Medaka) exposed to groundwater at Beach Point, Aberdeen Proving Ground, to indicate the toxic or carcinogenic potential of the groundwater and to determine the need for remediation. Medaka that were 14 days old were either exposed to 10 mg/l diethylnitrosamine (DEN) in water for 48 hours or were held under identical conditions with no DEN present. At 17 days of age the medaka were exposed to 0, 1 or 10% groundwater in the biomonitoring trailer at Beach Point. Laboratory controls were maintained at Ft. Detrick. After six months of exposure approximately one-third of the original 60 fish in each exposure group were euthanized and processed for histopathologic evaluation. The remainder of the fish in each exposure group were euthanized and evaluated after nine months of exposure. The study design is as follows:

Group No.	Treatment mg/L DEN; % Groundwater	No. of Fish for Evaluation 6 Mo. Sacrifice	No. of Fish for Evaluation 9 Mo. Sacrifice
1	0;0	20	27
2	0;0	20	34
3	10;0	20	25
4	10;0	20	36
5	0;1	21	36
6	0;1	20	37
7	10;1	20	33
8	10;1	20	38
9	0;10	20	37
10	0;10	20	34
11	10;10	20	33
12	10;10	20	40
17	0;Lab control	20	38
18	0;Lab control	20	38
19	10;Lab control	20	35
20	10;Lab control	20	34

Hematoxylin and eosin stained slides of each fish were prepared by Experimental Pathology Laboratories, Inc. Most fish were sampled by cutting five step sections through the fish in a longitudinal plane. In other fish, transverse sections were cut in certain areas (e.g. the head) in order to capture gross lesions that were described. In certain fish the lesions were sectioned separately. The following tissues were evaluated: bone (vertebra), brain, chromaffin tissue, corpuscle of Stannius, esophagus, eye, gallbladder, gill, heart,

hematopoietic tissue, interrenal tissue, intestine, kidney, liver, nares, ovary, pancreas, peripheral nerve, pineal organ, pituitary gland, pseudobranch, skeletal muscle, skin, spinal cord, spleen, stato-acoustic organ, swim bladder, testis, thymus, thyroid tissue, urinary bladder and gross lesions.

Tissues that were not present for examination in one or more medaka included bone (vertebra), chromaffin tissue, corpuscle of Stannius, eye, gallbladder, heart, interrenal tissue, nares, pineal organ, pituitary, spinal cord, spleen, thymus and urinary bladder. Occasional absence of these tissues is a condition inherent in the sectioning method.

Microscopic findings for each tissue examined from each medaka are listed in the Histopathology Incidence Tables by group and by sex. Inflammatory, degenerative and hyperplastic changes were graded from 1 to 5 depending upon severity. Neoplasms, cysts, developmental anomalies and other nongradable changes were designated as present (P). Tissues that were autolyzed are indicated with an "A," with or without additional diagnosis depending on the severity of the autolysis. Tissues of insufficient quantity for evaluation are indicated with an "I." All lesions are summarized by treatment group in the Incidence/Examined Summary by sex and with sexes combined with incidence expressed as numerator/denominator and percentage. Summary Incidence Tables by group and by disposition and sex, and by disposition with sexes combined, separate medaka which are part of a scheduled sacrifice from

those which died early. All neoplasms are also listed in the Neoplasm Summary Incidence Tables by group and by sex. A correlation of gross observations with the corresponding microscopic findings is presented in the Correlation of Gross and Microscopic Findings tables.

Medaka identified as Nos. 93-327-4-31 and 93-327-4-32 were not found among the fish submitted for histopathologic evaluation and are considered missing. Medaka from replicate Groups 1 and 2 probably intermingled and from replicate Groups 3 and 4 probably intermingled during a water backup in the biomonitoring trailer. Groups 1 and 2 did not intermingle with Groups 3 and 4.

## RESULTS

### 6-Month Interim Sacrifice

At six months, liver neoplasms (hepatocellular adenoma and carcinoma) occurred only among medaka in the biomonitoring trailer that were pre-exposed to DEN. Most neoplasms occurred in medaka that were also exposed to 10% groundwater. Hepatocellular carcinomas occurred only in medaka exposed to DEN and 10% groundwater. No liver neoplasia was present among the laboratory controls. Foci of cellular alteration occurred in groups exposed to DEN and in groups not exposed to DEN, but the incidence was higher in groups exposed to DEN. See Table I for a tabulation of liver neoplasia and foci of cellular alteration in medaka after six months of exposure to groundwater. The replicate groups are combined in this synopsis.

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TABLE I

INCIDENCE OF LIVER NEOPLASIA AND FOCI OF CELLULAR ALTERATION  
IN MEDAKA AFTER SIX MONTHS OF EXPOSURE TO GROUNDWATER

Exposure: DEN	No DEN	DEN	No DEN	DEN	No DEN	DEN	No DEN	DEN
Groundwater	0%	0%	1%	1%	10%	10%	None	None
Group Number	1 & 2	3 & 4	5 & 6	7 & 8	9 & 10	11 & 12	17 & 18*	19 & 20*
LIVER (Total No. Fish)	(40)	(40)	(41)	(40)	(40)	(40)	(40)	(40)
Hepatocellular Adenoma	-	2	-	1	-	4	-	-
Hepatocellular Carcinoma	-	-	-	-	-	3	-	-
Basophilic Focus (Foci)	-	1	1	2	-	1	-	-
Eosinophilic Focus (Foci)	-	2	-	5	-	3	1	3
Eosinophilic Area	1	-	1	-	-	-	-	-

\*Groups 17, 18, 19 and 20 are laboratory controls.

Neoplasms unrelated to treatment that occurred in individual medaka included a lymphosarcoma in the thymus of a Group 3 medaka, a seminoma in the testis of a Group 1 medaka and a seminoma in the ovary of a Group 10 medaka.

Granulomatous inflammation of the subcutaneous tissue of the lower jaw and/or upper jaw which was unrelated to exposure occurred only in male medaka. One to three medaka out of 20 or 21 total fish were affected in each of Groups 1, 2, 3, 4, 5, 6, 9 and 11, but not in any of the laboratory control groups.

Granulomas and/or granulomatous inflammation occurred sporadically among males and females in a variety of other tissues including adipose tissue of the head and cranial cavity, choroid rete of the eye, heart, hematopoietic tissue, liver, mesentery, oral cavity

submucosa, ovary, pericardial cavity, pseudobranch, skeletal muscle and urinary bladder. These lesions were not related to exposure.

Increased basophilia of thyroid tissue was diagnosed in medaka in all groups, but the incidence was greater among males than among females. The change was characterized by basophilic cuboidal follicular cells that form numerous small follicles with a small amount of colloid in contrast to follicles that are variable in size, distended with colloid and lined by flattened follicular cells. The reason for this basophilic appearance of the thyroid tissue, especially among male medaka, is not known.

Other changes occurred in a variety of tissues in medaka of both control and exposed groups, but these lesions either were present in small numbers of medaka or were distributed among the control and exposed groups such that there was no apparent relationship to exposure.

#### 9-Month Final Sacrifice

At nine months, liver neoplasms [hepatocellular adenoma and carcinoma; carcinoma, not otherwise specified (NOS); and cholangioma] occurred in medaka pre-exposed to DEN that were subsequently exposed to 0, 1 and 10% groundwater and in two Group 9 medaka exposed to 10% groundwater and no DEN. The occurrence of hepatocellular adenomas and carcinomas is neither dose related nor exposure related among the medaka pre-exposed to DEN and housed in the biomonitoring trailer. Among the control medaka held at the Fort Detrick laboratory, 3 of 69 fish pre-exposed to DEN had hepatocellular adenomas. Foci of cellular alteration

occurred in groups exposed to DEN and in groups not exposed to DEN, but the incidence was higher in groups exposed to DEN. See Table II for a tabulation of liver neoplasia and foci of cellular alteration in medaka after nine months of exposure to groundwater. The replicate groups are combined in this synopsis.

TABLE II

INCIDENCE OF LIVER NEOPLASIA AND FOCI OF CELLULAR ALTERATION  
IN MEDAKA AFTER NINE MONTHS OF EXPOSURE TO GROUNDWATER

Exposure: DEN	No DEN	DEN	No DEN	DEN	No DEN	DEN	No DEN	DEN
Groundwater	0%	0%	1%	1%	10%	10%	None	None
Group Number	1 & 2	3 & 4	5 & 6	7 & 8	9 & 10	11 & 12	17 & 18*	19 & 20*
LIVER (Total No.)**	(61)	(61)	(73)	(71)	(71)	(73)	(76)	(69)
Carcinoma, NOS	-	-	-	-	-	1	-	-
Hepatocellular Adenoma	-	4	-	4	1	5	-	3
Hepatocellular Adenoma, Multiple	-	1	-	1	-	1	-	-
Hepatocellular Carcinoma	-	2	-	-	1	2	-	-
Hepatocellular Carcinoma, Multiple	-	1	-	-	-	-	-	-
Cholangioma	-	-	-	-	-	1	-	-
Basophilic Area	-	-	-	1	-	1	-	-
Basophilic Focus (Foci)	-	3	1	3	1	5	-	1
Clear Cell Focus	-	-	-	-	1	-	-	-
Eosinophilic Focus (Foci)	-	4	-	4	1	4	1	5

\*Groups 17, 18, 19 and 20 are laboratory controls.

\*\*Total number of tissues evaluated includes those from medaka that died early or were sacrificed at nine months.

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Neoplasms unrelated to treatment that occurred in individual medaka included lymphosarcoma in a single medaka of Groups 1, 3, 11 and 18 and in two medaka from Group 7; a thyroid follicular cell adenoma in a Group 5 medaka; a thyroid follicular cell carcinoma in a Group 9 medaka; a testicular seminoma in a Group 12 medaka; a hemangioma in the gills of a Group 17 medaka; a gallbladder papilloma in a Group 17 medaka and an ovarian seminoma in a Group 20 medaka.

Granulomatous inflammation of the lower and/or upper jaw occurred among medaka in all exposure groups, and was more commonly seen in male medaka than female medaka. The lesion was often described grossly as an enlarged or thickened lower or upper jaw or lip. Associated with the inflammation in some cases was an increase in the amount of connective tissue in the area in the form of cartilage, bone or fibrous connective tissue. A number of medaka, but not all, with granulomatous inflammation of the jaw also had granulomas or granulomatous inflammation in one or more other tissues such as the choroid rete of the eye, heart, hematopoietic tissue, liver, mesentery, oral cavity, pseudobranch and spleen. Other medaka had granulomatous lesions of one or more tissues, but no jaw lesions.

Tissues from two Group 2 male medaka (2-25 and 2-34), one Group 3 female medaka (3-50), one Group 18 male medaka (18-34) and one Group 20 female medaka (20-52) were stained with an acid-fast stain. In the Group 2 medaka, acid-fast positive organisms were present in the



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granulomatous lesions of the jaws as well as in other tissues with granulomatous lesions. In the Group 18 medaka, acid-fast organisms were present in the granulomas that were described only in the hematopoietic tissue. In the Group 3 and Group 20 medaka, acid-fast organisms were found in several tissues including gills, hematopoietic tissue, liver and mesentery.

Granulomas in the heart, hematopoietic tissue, liver and spleen occurred in medaka in almost all groups housed in the biomonitoring trailer. Among the laboratory controls, granulomas in one or more of these tissues were found only in Groups 18, 19 and 20 and among these three groups, the highest incidence was in Group 20 medaka, e.g., 15 of 34 had granulomas in the hematopoietic tissue and/or liver). With a few exceptions in granulomas of the heart, liver and spleen, and without exception in the hematopoietic tissue, the incidence of these granulomas was higher among male medaka than among female medaka. Among the groups housed in the trailer, the highest incidence of granulomas in these four tissues occurred among the control groups exposed to 0% groundwater, and the lowest incidence occurred among the groups exposed to 10% groundwater. See Table III for a tabulation of the incidence of these granulomas in the medaka housed in the biomonitoring trailer and the laboratory with the incidence from the replicate groups combined and males and females combined.

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TABLE III

INCIDENCE OF GRANULOMAS IN SELECTED TISSUES FROM MEDAKA  
AFTER NINE MONTHS OF EXPOSURE TO GROUNDWATER

Exposure: DEN	No DEN	DEN	No DEN	DEN	No DEN	DEN	No DEN	DEN
Groundwater	0%	0%	1%	1%	10%	10%	None	None
Group Number	1 & 2	3 & 4	5 & 6	7 & 8	9 & 10	11 & 12	17 & 18*	19 & 20*
HEART (Total No.)**	(61)	(61)	(73)	(69)	(71)	(73)	(76)	(69)
Granulomas	12	22	9	9	5	4	0	6
HEMATOPOIETIC TISSUE (Total No.)**	(61)	(61)	(73)	(71)	(71)	(73)	(76)	(69)
Granulomas	29	28	17	14	7	7	1	16
LIVER (Total No.)**	(61)	(61)	(73)	(71)	(71)	(73)	(76)	(69)
Granulomas	37	31	24	22	10	13	0	16
SPLEEN (Total No.)**	(60)	(56)	(64)	(67)	(63)	(62)	(65)	(61)
Granulomas	12	12	11	5	5	2	0	8

\*Groups 17, 18, 19 and 20 are laboratory controls.

\*\*Total number of tissues evaluated includes those from medaka that died early or were sacrificed at nine months.

Of the 35 medaka that died early and were evaluated histologically, nine were females and 26 were males. None were from the laboratory control groups. They consisted of one or more fish from all exposure groups in the biomonitoring trailer except for Group 11. None of these 35 fish had liver neoplasms. All of the males that died early except one had granulomatous lesions of two or more tissues. In male medaka No. 1-34 the cause of death was not apparent. Male medaka No. 7-30 had lymphosarcoma and No. 9-23 had a thyroid follicular cell carcinoma in addition to granulomatous lesions. Of the nine females that died early, three had granulomatous lesions of numerous tissues. Medaka No. 2-27 had a granulomatous lesion of the caudal fin.

Lymphosarcoma occurred in medaka Nos. 1-27 and 7-26. Medaka Nos. 5-24 and 7-29 had egg impaction, and in medaka No. 8-23 moderately severe degenerative ova may have caused the bloated condition described before the fish was euthanized.

Cystic degeneration (spongiosis hepatitis) in the liver occurred in all exposure groups and was more common among females than males. The incidence in the laboratory controls overall (29 of 145 total fish) was less than in the groups in the biomonitoring trailer exposed to 0% (54 of 122), 1% (58 of 144) or 10% (46 of 144) groundwater. The severity varied from minimal to moderately severe, but was minimal to mild in the majority of the medaka with the lesion.

Hepatic cysts occurred in the liver in all exposure groups, but the incidence in the laboratory controls overall was less than in the groups in the biomonitoring trailer.

Vacuolated hepatocyte foci in the liver occurred in all exposure groups, but the incidence was less in controls (18 of 145 laboratory controls, 12 of 122 trailer controls) than in medaka exposed to 1% (32 of 144) or 10% (26 of 144) groundwater.

Fusion of gill lamellae occurred in male and female medaka in all the exposure groups and was more common among females than males. There was a slight increase in incidence of the gill change overall in the medaka exposed to 10% groundwater (Groups 9, 10, 11, 12); however, the severity of the change, which was usually minimal to mild, was similar among all the exposure groups.

Increased basophilia of thyroid tissue, characterized as stated in the discussion of the medaka from the six-month interim sacrifice, was diagnosed in medaka from all exposure groups. The incidence was approximately three times greater among males than among females but in almost all cases the severity was minimal to mild.

Other changes occurred in a variety of tissues in medaka of both control and exposed groups, but these lesions either were present in small numbers of medaka or were distributed among the groups such that there was no apparent relationship to exposure.

#### CONCLUSIONS

After six months of exposure to 0, 1 or 10% groundwater, liver neoplasia (hepatocellular adenoma and carcinoma) occurred in medaka that had been previously initiated with DEN. Seven of 40 medaka were affected in the groups exposed to 10% groundwater as compared to two of 40 among the controls and one of 40 medaka exposed to 1% groundwater. There were no liver neoplasms among the laboratory controls.

After nine months, hepatocellular adenomas or carcinomas, single or multiple, occurred in DEN-initiated medaka that had been exposed to 0, 1 and 10% groundwaters such that there were as many neoplasms among the controls (8 of 122) as among the 10% exposure group (8 of 144). There were two liver neoplasms (one hepatocellular adenoma and one carcinoma) in medaka exposed to 10% groundwater, but no DEN. Two additional liver neoplasms not related to hepatocytes occurred in

the DEN-10% groundwater exposure Group 12. One was a cholangioma and the other was a carcinoma, cell of origin unknown. In the DEN-1% groundwater exposure groups there were five (5 of 144) hepatocellular neoplasms, all adenomas. At nine months there was no dose-related response for liver neoplasia in medaka exposed to groundwater. There were three hepatocellular adenomas diagnosed among the DEN-initiated laboratory controls.

Other neoplasms that occurred sporadically among the various exposure groups at six months and nine months included lymphosarcoma, seminoma, thyroid follicular cell adenoma, thyroid follicular cell carcinoma, hemangioma of the gills and a gallbladder papilloma.

Granulomatous inflammation of the subcutaneous tissue of the lower and/or upper jaw occurred in small numbers of male medaka in the biomonitoring trailer (one to three medaka in each group except Groups 7, 8, 10 and 12) at six months. The same lesion occurred among medaka of all exposure groups, including laboratory controls, at nine months. The incidence was substantially greater among males than among females; for example, 144 males overall versus 17 females were diagnosed with granulomatous inflammation of the lower jaw. Granulomatous inflammation or granulomas occurred in a variety of additional tissues among medaka of all exposure groups. Acid-fast staining of five representative medaka was positive for the presence of acid-fast organisms in granulomatous lesions. The reason for the higher incidence of these lesions in males versus females is not known. Trauma may be an

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initiating factor in the granulomatous lesions of the jaws, but the reason why the jaws of these medaka should be traumatized is not known.

Granulomas in the heart, hematopoietic tissue, liver and spleen occurred in the highest incidence in controls in the biomonitoring trailer and in the lowest incidence in medaka exposed to 10% groundwater. See Table III. The reasons for this lower incidence among medaka exposed to 10% groundwater as compared to controls is not known.

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*August 26, 1994*

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APPENDIX 48

COMPREHENSIVE CHEMICAL ANALYSES CONDUCTED ON RAW  
(pH  $\approx$ 4) BEACH POINT GROUNDWATER (WELL CC-33B)  
AND CHRONIC HISTOPATHOLOGY EXPOSURE TANKS

TABLE A48-1. RESULTS OF THE APG-EA BEACH POINT GROUNDWATER AND DILUENT WATER  
COMPREHENSIVE CHEMICAL ANALYSES (TEST NO. 1) - GENERAL WATER QUALITY<sup>a</sup>

Parameter	Method	Detection Limits	100% G.W.	10% G.W.	1% G.W.	Diluent H <sub>2</sub> O
Total Alkalinity (CaCO <sub>3</sub> )	EPA 310.1	5	b	21	28	26
Ammonia (N)	EPA 350.1	0.02	0.029	0.025	0.029	0.027
Chloride (Cl)	EPA 300.0	0.5	490	86.7	31.2	21.9
Total Cyanide (CN)	EPA 335.2	10	ND	ND	ND	ND
Fluoride (F)	EPA 300.0	0.2	1.2	0.66	0.55	0.84
Hardness, (CaCO <sub>3</sub> )	SM2540B		170	73	62	59
Nitrate (N)	EPA 300.0	0.1	0.14	1.5	1.7	4.3
Nitrite (N)	b	b	b	b	b	b
Total Phosphate (P)	EPA 365.4	0.01	2.64	3.13	0.26	0.54
Total Suspended Solids	EPA 160.2	5	ND	ND	ND	ND
Specific Conductance	EPA 120.1		1600	265	175	169
Sulfate (SO <sub>4</sub> )	EPA 300.0	0.5	91.2	34.2	29.3	28.1
Sulfide (S)	EPA 376.1	5	180	350	360	330
TOC	EPA 415.2	1	4	2	ND	ND
Bromide (Br)	EPA 300.0	0.1	1.5	0.16	ND	ND

<sup>a</sup> All results expressed as mg/L except for specific conductance which is expressed as  $\mu\text{mhos/cm}$ .

<sup>b</sup> Analysis not conducted by Vendor.



TABLE A48-1. (CONTINUED) - METALS<sup>a</sup>

Parameter	Method	Detection Limits	100% G.W.	10% G.W.	1% G.W.	Diluent H <sub>2</sub> O
Aluminum (Al)	EPA 200.7	40	810	64	ND	ND
Antimony (Sb)	EPA 200.7	20	ND	ND	ND	ND
Arsenic (As)	EPA 206.2	5	ND	ND	ND	ND
Beryllium (Be)	EPA 200.7	5	ND	ND	ND	ND
Boron (B)	EPA 200.7	50	54	51	ND	ND
Cadmium (Cd)	EPA 213.2	0.5	0.76	ND	ND	ND
Calcium (Ca)	EPA 200.7	500	16500	17300	17200	16700
Chromium (Cr)	EPA 200.7	5	ND	ND	ND	ND
Cobalt (Co)	EPA 200.7	40	110	ND	ND	ND
Copper (Cu)	EPA 200.7	5	5.4	ND	ND	ND
Iron (Fe)	EPA 200.7	100	4600	340	ND	ND
Lead (Pb)	EPA 239.2	5	ND	ND	ND	ND
Magnesium (Mg)	EPA 200.7	500	31300	7290	4590	4230
Manganese (Mn)	EPA 200.7	15	1860	200	22	ND
Mercury (Hg)	EPA 245.1	0.5	ND	ND	ND	ND
Molybdenum (Mo)	EPA 200.7	40	ND	ND	ND	ND
Nickel (Ni)	EPA 200.7	8	120	13	ND	ND
Potassium (K)	EPA 258.1	100	4130	2050	1760	1710
Selenium (Se)	EPA 270.2	5	ND	ND	ND	ND
Silver (Ag)	EPA 272.2	0.5	ND	ND	ND	ND
Sodium (Na)	EPA 200.7	500	257000	39200	12400	9260
Thallium (Tl)	EPA 279.2	5	ND	ND	ND	ND
Tin (Sn)	EPA 200.7	100	ND	ND	ND	ND
Zinc (Zn)	EPA 200.7	5	210	170	160	160

<sup>a</sup> Results expressed as µg/L.

TABLE A48-1. (CONTINUED) - PURGEABLE ORGANIC COMPOUNDS<sup>a</sup>

Parameter	Method	Detection Limits	100% G.W.	10% G.W.	1% G.W.	Diluent H <sub>2</sub> O
Benzene	EPA 524.2	1	ND	ND	ND	ND
Bromobenzene	EPA 524.2	1	ND	ND	ND	ND
Bromochloromethane	EPA 524.2	1	ND	ND	ND	ND
Bromodichloromethane	EPA 524.2	1	ND	ND	ND	ND
Bromoform	EPA 524.2	1	ND	ND	ND	ND
Bromomethane	EPA 524.2	1	ND	ND	ND	ND
Carbon tetrachloride	EPA 524.2	1	ND	ND	ND	ND
Chlorobenzene	EPA 524.2	1	2	ND	ND	ND
Chloroethane	EPA 524.2	1	ND	ND	ND	ND
Chloroform	EPA 524.2	1	10	1	ND	ND
Chloromethane	EPA 524.2	1	ND	ND	ND	ND
2-Chlorotoluene	EPA 524.2	1	ND	ND	ND	ND
4-Chlorotoluene	EPA 524.2	1	ND	ND	ND	ND
Dibromochloromethane	EPA 524.2	1	ND	ND	ND	ND
1,2-Dibromo-3-chloropropane	EPA 524.2	1	ND	ND	ND	ND
1,2-Dibromoethane	EPA 524.2	1	ND	ND	ND	ND
Dibromomethane	EPA 524.2	1	ND	ND	ND	ND
1,2-Dichlorobenzene	EPA 524.2	1	ND	ND	ND	ND
1,3-Dichlorobenzene	EPA 524.2	1	ND	ND	ND	ND
1,4-Dichlorobenzene	EPA 524.2	1	ND	ND	ND	ND
Dichlorodifluoromethane	EPA 524.2	1	ND	ND	ND	ND
1,1-Dichloroethane	EPA 524.2	1	ND	ND	ND	ND
1,2-Dichloroethane	EPA 524.2	1	ND	ND	ND	ND
1,1-Dichloroethene	EPA 524.2	1	1	ND	ND	ND
cis-1,2-Dichloroethene	EPA 524.2	1	430	27	ND	ND
trans-1,2-Dichloroethene	EPA 524.2	1	ND	ND	ND	ND
1,2-Dichloropropane	EPA 524.2	1	ND	ND	ND	ND

<sup>a</sup> Results expressed as µg/L.

TABLE A48-1. (CONTINUED) - PURGEABLE ORGANIC COMPOUNDS CON'T<sup>a</sup>

Parameter	Method	Detection Limits	100% G.W.	10% G.W.	1% G.W.	Diluent H <sub>2</sub> O
1,3-Dichloropropane	EPA 524.2	1	ND	ND	ND	ND
2,2-Dichloropropane	EPA 524.2	1	ND	ND	ND	ND
1,1-Dichloropropene	EPA 524.2	1	ND	ND	ND	ND
cis-1,3-Dichloropropene	EPA 524.2	1	ND	ND	ND	ND
trans-1,3-Dichloropropene	EPA 524.2	1	ND	ND	ND	ND
Ethylbenzene	EPA 524.2	1	ND	ND	ND	ND
Methylene chloride	EPA 524.2	1	ND	ND	ND	ND
Styrene	EPA 524.2	1	ND	ND	ND	ND
1,1,1,2-Tetrachloroethane	EPA 524.2	1	3	ND	ND	ND
1,1,2,2-Tetrachloroethane	EPA 524.2	1	10000	1400	ND	7
Tetrachloroethene	EPA 524.2	1	90	6	ND	ND
Toluene	EPA 524.2	1	ND	ND	ND	ND
1,1,1-Trichloroethane	EPA 524.2	1	ND	ND	ND	ND
1,1,2-Trichloroethane	EPA 524.2	1	90	8	ND	1
Trichloroethene	EPA 524.2	1	1400	80	ND	ND
Trichlorofluoromethane	EPA 524.2	1	ND	ND	ND	ND
1,2,3-Trichloropropane	EPA 524.2	1	ND	ND	ND	ND
Vinyl chloride	EPA 524.2	1	2	ND	ND	ND
o-Xylene	EPA 524.2	1	ND	ND	ND	ND
m-Xylene	EPA 524.2	1	ND	ND	ND	ND
p-Xylene	EPA 524.2	1	ND	ND	ND	ND

<sup>a</sup> Results expressed as µg/L.

TABLE A48-1. (CONTINUED) - ORGANIC COMPOUNDS<sup>a</sup>

Parameter	Method	Detection Limits	100% G.W.	10% G.W.	1% G.W.	Diluent H <sub>2</sub> O
Acenaphthene	EPA 525	10	ND	ND	ND	ND
Acenaphthylene	EPA 525	10	ND	ND	ND	ND
Anthracene	EPA 525	10	ND	ND	ND	ND
Benzidine	EPA 525	20	ND	ND	ND	ND
Benzo[a]anthracene	EPA 525	10	ND	ND	ND	ND
Benzo[b]fluoranthene	EPA 525	10	ND	ND	ND	ND
Benzo[k]fluoranthene	EPA 525	10	ND	ND	ND	ND
Benzo[a]pyrene	EPA 525	10	ND	ND	ND	ND
Benzo[g,h,i]perylene	EPA 525	10	ND	ND	ND	ND
Butyl Benzyl Phthalate	EPA 525	10	ND	ND	ND	ND
Bis (2-chloroethyl) Ether	EPA 525	10	ND	ND	ND	ND
Bis (2-chloroethoxy) Methane	EPA 525	10	ND	ND	ND	ND
Bis (2-ethylhexyl) Phthalate	EPA 525	10	ND	ND	ND	ND
Bis (2-chloroisopropyl) Ether	EPA 525	10	ND	ND	ND	ND
4-Bromophenyl Phenyl Ether	EPA 525	10	ND	ND	ND	ND
2-Chloronaphthalene	EPA 525	10	ND	ND	ND	ND
4-Chlorophenyl Phenyl Ether	EPA 525	10	ND	ND	ND	ND
Chrysene	EPA 525	10	ND	ND	ND	ND
Dibenzo (a,h) Anthracene	EPA 525	10	ND	ND	ND	ND
Di-n-Butylphthalate	EPA 525	10	ND	ND	ND	ND
1,3-Dichlorobenzene	EPA 525	10	ND	ND	ND	ND
1,2-Dichlorobenzene	EPA 525	10	ND	ND	ND	ND
1,4-Dichlorobenzene	EPA 525	10	ND	ND	ND	ND
3,3'-Dichlorobenzidine	EPA 525	20	ND	ND	ND	ND
1,2-Diphenylhydrazine	EPA 525	20	ND	ND	ND	ND
Diethyl Phthalate	EPA 525	10	ND	ND	ND	ND
Dimethyl Phthalate	EPA 525	10	ND	ND	ND	ND
2,4-Dinitrotoluene	EPA 525	10	ND	ND	ND	ND
2,6-Dinitrotoluene	EPA 525	10	ND	ND	ND	ND

<sup>a</sup> Results expressed as µg/L.

TABLE A48-1. (CONTINUED) - ORGANIC COMPOUNDS CON'T<sup>a</sup>

Parameter	Method	Detection Limits	100% G.W.	10% G.W.	1% G.W.	Diluent H <sub>2</sub> O
Di-n-octylphthalate	EPA 525	10	ND	ND	ND	ND
Fluoranthene	EPA 525	10	ND	ND	ND	ND
Fluorene	EPA 525	10	ND	ND	ND	ND
Hexachlorobenzene	EPA 525	10	ND	ND	ND	ND
Hexachlorobutadiene	EPA 525	10	ND	ND	ND	ND
Hexachloroethane	EPA 525	10	ND	ND	ND	ND
Hexachlorocyclopentadiene	EPA 525	10	ND	ND	ND	ND
Indeno[1,2,3,c,d]pyrene	EPA 525	10	ND	ND	ND	ND
Isophorone	EPA 525	10	ND	ND	ND	ND
Naphthalene	EPA 525	10	ND	ND	ND	ND
Nitrobenzene	EPA 525	10	ND	ND	ND	ND
N-Nitrosodi-n-propylamine	EPA 525	10	ND	ND	ND	ND
N-Nitrosodimethylamine	EPA 525	10	ND	ND	ND	ND
N-Nitrosodiphenylamine	EPA 525	10	ND	ND	ND	ND
Phenanthrene	EPA 525	10	ND	ND	ND	ND
Pyrene	EPA 525	10	ND	ND	ND	ND
1,2,4-Trichlorobenzene	EPA 525	10	ND	ND	ND	ND
4-Chloro-3-methylphenol	EPA 525	10	ND	ND	ND	ND
2-Chlorophenol	EPA 525	10	ND	ND	ND	ND
2,4-Dichlorophenol	EPA 525	10	ND	ND	ND	ND
2,4-Dimethylphenol	EPA 525	10	ND	ND	ND	ND
2,4-Dinitrophenol	EPA 525	50	ND	ND	ND	ND
2-Methyl-4,6-dinitrophenol	EPA 525	50	ND	ND	ND	ND
2-Nitrophenol	EPA 525	10	ND	ND	ND	ND
4-Nitrophenol	EPA 525	50	ND	ND	ND	ND
Pentachlorophenol	EPA 525	50	ND	ND	ND	ND
Phenol	EPA 525	10	ND	ND	ND	ND
2,4,6-Trichlorophenol	EPA 525	10	ND	ND	ND	ND

<sup>a</sup> Results expressed as µg/L.

TABLE A48-1. (CONTINUED) - CHLORINATED PESTICIDES<sup>a</sup>

Parameter	Method	Detection Limits	100% G.W.	10% G.W.	1% G.W.	Diluent H <sub>2</sub> O
Aldrin	EPA 508	0.01	ND	ND	ND	ND
Chlordane-alpha	EPA 508	0.01	ND	ND	ND	ND
Chlordane-gamma	EPA 508	0.01	ND	ND	ND	ND
Chloroneb	EPA 508	0.01	ND	ND	ND	ND
Chlorobenzilate(a)	EPA 508	0.01	ND	ND	ND	ND
Chlorothalonil	EPA 508	0.01	ND	ND	ND	ND
DCPA	EPA 508	0.01	ND	ND	ND	ND
4,4'-DDD	EPA 508	0.01	ND	ND	ND	ND
4,4'-DDE	EPA 508	0.01	ND	ND	ND	ND
4,4'-DDT	EPA 508	0.01	ND	ND	ND	ND
Dieldrin	EPA 508	0.01	ND	ND	ND	ND
Endosulfan I	EPA 508	0.01	ND	ND	ND	ND
Endosulfan II	EPA 508	0.01	ND	ND	ND	ND
Endosulfan sulfate	EPA 508	0.01	ND	ND	ND	ND
Endrin	EPA 508	0.01	ND	ND	ND	ND
Endrin aldehyde	EPA 508	0.01	ND	ND	ND	ND
Etridiazole	EPA 508	0.01	ND	ND	ND	ND
HCH-alpha	EPA 508	0.01	ND	ND	ND	ND
HCH-beta	EPA 508	0.01	ND	ND	ND	ND
HCH-delta(a)	EPA 508	0.01	ND	ND	ND	ND
HCH-gamma(Lindane)	EPA 508	0.01	ND	ND	ND	ND
Heptachlor	EPA 508	0.01	ND	ND	ND	ND
Heptachlor epoxide	EPA 508	0.01	ND	ND	ND	ND
Hexachlorobenzene	EPA 508	0.01	ND	ND	ND	ND
Methoxychlor	EPA 508	0.01	ND	ND	ND	ND
cis-Permethrin	EPA 508	0.01	ND	ND	ND	ND
trans-Permethrin	EPA 508	0.01	ND	ND	ND	ND
Propachlor	EPA 508	0.01	ND	ND	ND	ND

<sup>a</sup> Results expressed as µg/L.

TABLE A48-1. (CONTINUED) - CHLORINATED PESTICIDES CON'T<sup>a</sup>

Parameter	Method	Detection Limits	100% G.W.	10% G.W.	1% G.W.	Diluent H <sub>2</sub> O
Trifluralin	EPA 508	0.01	ND	ND	ND	ND
Toxaphene	EPA 508	0.5	ND	ND	ND	ND
Chlordane	EPA 508	0.08	ND	ND	ND	ND
Aroclor 1016	EPA 508	0.1	ND	ND	ND	ND
Aroclor 1221	EPA 508	0.1	ND	ND	ND	ND
Aroclor 1232	EPA 508	0.1	ND	ND	ND	ND
Aroclor 1242	EPA 508	0.1	ND	ND	ND	ND
Aroclor 1248	EPA 508	0.1	ND	ND	ND	ND
Aroclor 1254	EPA 508	0.1	ND	ND	ND	ND
Aroclor 1260	EPA 508	0.1	ND	ND	ND	ND

<sup>a</sup> Results expressed as µg/L.

TABLE A48-1. (CONTINUED) - ORGANOPHOSPHORUS PESTICIDES AND CHLORINATED ACIDS<sup>a</sup>

Parameter	Method	Detection Limits	100% G.W.	10% G.W.	1% G.W.	Diluent H <sub>2</sub> O
<u>Organophosphorus Pesticides:</u>						
Malathion	EPA 614	0.2	ND	ND	ND	ND
Parathion	EPA 614	0.2	ND	ND	ND	ND
Dursban	EPA 614	0.2	ND	ND	ND	ND
<u>Chlorinated Acids:</u>						
Acifluorfen	EPA 515.1	0.05	ND	ND	ND	ND
Bentazon	EPA 515.1	0.05	ND	ND	ND	ND
Chloramben	EPA 515.1	0.05	ND	ND	ND	ND
2,4-D	EPA 515.1	0.05	ND	ND	ND	ND
Dalapon	EPA 515.1	0.05	ND	ND	ND	ND
2,4-DB	EPA 515.1	0.05	ND	ND	ND	ND
Dicamba	EPA 515.1	0.05	ND	ND	ND	ND
3,5-Dichlorobenzoic acid	EPA 515.1	0.05	ND	ND	ND	ND
Dichlorprop	EPA 515.1	0.05	ND	ND	ND	ND
Dinoseb	EPA 515.1	0.05	ND	ND	ND	ND
5-Hydroxydicamba	EPA 515.1	0.05	ND	ND	ND	ND
4-Nitrophenol	EPA 515.1	0.05	ND	ND	ND	ND
Pentachlorophenol (PCP)	EPA 515.1	0.05	ND	ND	ND	ND
Picloram	EPA 515.1	0.05	ND	ND	ND	ND
2,4,5-T	EPA 515.1	0.05	ND	ND	ND	ND
Methyl 2,4,5-TP	EPA 515.1	0.05	ND	ND	ND	ND
DCPA acid metabolites(a)	EPA 515.1	0.05	ND	ND	ND	ND

<sup>a</sup> Results expressed as µg/L.



TABLE A48-1. (CONTINUED) - NITROGEN AND PHOSPHOROUS-CONTAINING PESTICIDES<sup>a</sup>

Parameter	Method	Detection Limits	100% G.W.	10% G.W.	1% G.W.	Diluent H <sub>2</sub> O
Alachlor	EPA 507	0.2	ND	ND	ND	ND
Ametryn	EPA 507	0.25	ND	ND	ND	ND
Atraton	EPA 507	0.2	ND	ND	ND	ND
Atrazine	EPA 507	0.25	ND	ND	ND	ND
Bromacil	EPA 507	0.2	ND	ND	ND	ND
Butachlor	EPA 507	0.2	ND	ND	ND	ND
Butylate	EPA 507	0.2	ND	ND	ND	ND
Carboxin	EPA 507	0.2	ND	ND	ND	ND
Chlorpropham	EPA 507	0.2	ND	ND	ND	ND
Cycloate	EPA 507	0.25	ND	ND	ND	ND
Diazinon(a)	EPA 507	0.2	ND	ND	ND	ND
Dichlorvos	EPA 507	0.2	ND	ND	ND	ND
Diphenamid	EPA 507	0.25	ND	ND	ND	ND
Disulfoton	EPA 507	0.25	ND	ND	ND	ND
Disulfoton sulfone	EPA 507	0.2	ND	ND	ND	ND
EPTC	EPA 507	0.25	ND	ND	ND	ND
Ethoprop	EPA 507	0.25	ND	ND	ND	ND
Fenamiphos	EPA 507	0.25	ND	ND	ND	ND
Fenarimol	EPA 507	0.2	ND	ND	ND	ND
Fluridone	EPA 507	1.0	ND	ND	ND	ND
Hexazinone	EPA 507	0.2	ND	ND	ND	ND
Merphos	EPA 507	0.25	ND	ND	ND	ND
Metolachlor	EPA 507	0.2	ND	ND	ND	ND
Metribuzin	EPA 507	0.2	ND	ND	ND	ND
Mevinphos	EPA 507	0.25	ND	ND	ND	ND
MGK 264	EPA 507	0.2	ND	ND	ND	ND
Molinate	EPA 507	0.2	ND	ND	ND	ND

<sup>a</sup> Results expressed as µg/L.

TABLE A48-1. (CONTINUED) - NITROGEN AND PHOSPHOROUS-CONTAINING PESTICIDES CON'T<sup>a</sup>

Parameter	Method	Detection Limits	100% G.W.	10% G.W.	1% G.W.	Diluent H <sub>2</sub> O
Napropamide	EPA 507	0.2	ND	ND	ND	ND
Norflurazon	EPA 507	0.2	ND	ND	ND	ND
Pebulate	EPA 507	0.2	ND	ND	ND	ND
Prometon	EPA 507	0.25	ND	ND	ND	ND
Prometryn	EPA 507	0.25	ND	ND	ND	ND
Pronamide(a)	EPA 507	0.2	ND	ND	ND	ND
Propazine	EPA 507	0.25	ND	ND	ND	ND
Simazine	EPA 507	0.25	ND	ND	ND	ND
Simetryn	EPA 507	0.2	ND	ND	ND	ND
Stirofos	EPA 507	0.2	ND	ND	ND	ND
Tebuthiuron	EPA 507	0.2	ND	ND	ND	ND
Terbacil	EPA 507	0.2	ND	ND	ND	ND
Terbufos(a)	EPA 507	0.2	ND	ND	ND	ND
Terbutryn	EPA 507	0.25	ND	ND	ND	ND
Triademefon	EPA 507	0.25	ND	ND	ND	ND
Tricyclazole	EPA 507	1.0	ND	ND	ND	ND
Vernolate	EPA 507	0.2	ND	ND	ND	ND

<sup>a</sup> Results expressed as µg/L.

TABLE A48-2. RESULTS OF THE APG-EA BEACH POINT GROUNDWATER AND DILUENT WATER  
COMPREHENSIVE CHEMICAL ANALYSES (TEST NO. 2) - GENERAL WATER QUALITY<sup>a</sup>

Parameter	Method	Detection Limits	100% G.W.	10% G.W.	1% G.W.	Diluent H <sub>2</sub> O
Total Alkalinity (CaCO <sub>3</sub> )	EPA 310.1	1	ND	25	30	31
Ammonia (N)	SM 4500-NH <sub>3</sub> E	0.1	ND	ND	ND	ND
Chloride (Cl)	EPA 325.3	1	580	68	26	21
Total Cyanide (CN)	EPA 335.3	0.01	0.06	ND	ND	ND
Fluoride (F)	EPA 340.2	0.05	0.36	0.88	0.94	0.94
Hardness, (CaCO <sub>3</sub> )	EPA 130.2	1	220	80	70	74
Nitrate (N)	EPA 353.2	0.1	2.5	3.2	2.3	2.5
Nitrite (N)	EPA 354.1	0.01	ND	ND	ND	ND
Total Phosphorus (P)	EPA 365.2	0.01	0.12	0.52	0.52	0.50
Total Suspended Solids	EPA 160.2	5	ND	ND	ND	ND
Specific Conductance	EPA 120.1	N/A	1760	356	213	200
Sulfate (SO <sub>4</sub> )	EPA 375.4	1	62	17	12	12
Sulfide (S)	EPA 376.1	1	ND	ND	ND	ND
TOC	EPA 415.1	1	4	ND	ND	ND
Bromide (Br)	SM 4500-Br	b	1.5	0.44	0.44	0.37

<sup>a</sup> All results expressed as mg/L except for specific conductance which is expressed as  $\mu\text{mohs/cm}$ .

<sup>b</sup> The detection limit was 0.5 mg/L for the 100% groundwater sample and 0.1 mg/L for the 10% and 1% groundwater and dilution water samples.

TABLE A48-2. (CONTINUED) - METALS<sup>a</sup>

Parameter	Method	Detection Limits	100% G.W.	10% G.W.	1% G.W.	Diluent H <sub>2</sub> O
Aluminum (Al)	EPA 200.7	0.1	1.1	ND	ND	ND
Antimony (Sb)	EPA 204.2	0.005	ND	ND	ND	ND
Arsenic (As)	EPA 206.2	0.005	ND	ND	ND	ND
Beryllium (Be)	EPA 200.7	0.005	ND	ND	ND	ND
Boron (B)	EPA 200.7	0.05	ND	ND	ND	ND
Cadmium (Cd)	EPA 213.2	0.0005	0.0008	0.0006	0.0007	0.0008
Calcium (Ca)	EPA 200.7	0.5	17	20	17	17
Chromium (Cr)	EPA 218.2	0.002	ND	ND	ND	ND
Cobalt (Co)	EPA 200.7	0.05	0.09	ND	ND	ND
Copper (Cu)	EPA 220.2	0.005	0.008	0.006	ND	ND
Iron (Fe)	EPA 200.7	0.1	5.4	0.5	0.1	ND
Lead (Pb)	EPA 239.2	0.005	ND	ND	ND	ND
Magnesium (Mg)	EPA 200.7	0.5	30	8.2	5.1	4.8
Manganese (Mn)	EPA 200.7	0.01	1.7	0.20	0.02	ND
Mercury (Hg)	EPA 245.1	0.0005	ND	ND	ND	ND
Molybdenum (Mo)	EPA 200.7	0.01	ND	ND	ND	ND
Nickel (Ni)	EPA 200.7	0.05	0.12	ND	ND	ND
Potassium (K)	EPA 200.7	0.5	2.5	2.0	1.8	1.7
Selenium (Se)	EPA 270.2	0.005	ND	ND	ND	ND
Silver (Ag)	EPA 272.2	0.001	ND	ND	ND	ND
Sodium (Na)	EPA 200.7	0.5	260	36	12	9.3
Thallium (Tl)	EPA 279.2	0.005	ND	ND	ND	ND
Tin (Sn)	EPA 282.2	0.005	ND	ND	ND	ND
Zinc (Zn)	EPA 200.7	0.05	0.24	0.16	0.13	0.12

<sup>a</sup> Results expressed as mg/L.

TABLE A48-2. (CONTINUED) - VOLATILES<sup>a</sup>

Parameter	Method	Detection Limits	100% G.W.	10% G.W.	1% G.W.	Diluent H <sub>2</sub> O
Chloromethane	EPA 8240	10	ND	ND	ND	ND
Bromomethane	EPA 8240	10	ND	ND	ND	ND
Vinyl chloride	EPA 8240	10	ND	ND	ND	ND
Chloroethane	EPA 8240	10	ND	ND	ND	ND
Methylene chloride	EPA 8240	5	ND	ND	ND	ND
Acrolein	EPA 8240	100	ND	ND	ND	ND
Acrylonitrile	EPA 8240	100	ND	ND	ND	ND
Trichlorofluoromethane	EPA 8240	5	ND	ND	ND	ND
1,1-Dichloroethane	EPA 8240	5	ND	ND	ND	ND
1,2-Dichloroethene	EPA 8240	5	640	33	<sup>b</sup>	ND
Chloroform	EPA 8240	5	11	ND	ND	ND
1,2-Dichloroethane	EPA 8240	5	ND	ND	ND	ND
1,1,1-Trichloroethane	EPA 8240	5	ND	ND	ND	ND
Carbon tetrachloride	EPA 8240	5	ND	ND	ND	ND
Bromodichloromethane	EPA 8240	5	ND	ND	ND	ND
1,2-Dichloropropane	EPA 8240	5	ND	ND	ND	ND
1,3-Dichloropropene	EPA 8240	5	ND	ND	ND	ND
Dibromochloromethane	EPA 8240	5	ND	ND	ND	ND
1,1,2-Trichloroethane	EPA 8240	5	110	8	ND	ND
2-Chloroethylvinyl ether	EPA 8240	10	ND	ND	ND	ND
Bromoform	EPA 8240	5	ND	ND	ND	ND
Tetrachloroethene	EPA 8240	5	90	5	ND	ND
1,1,2,2-Tetrachloroethane	EPA 8240	5	17000	1300	160	9
Ethylbenzene	EPA 8240	5	ND	ND	ND	ND
1,1-Dichloroethene	EPA 8240	5	ND	ND	ND	ND
Trichloroethene	EPA 8240	5	1600	80	7	ND
Benzene	EPA 8240	5	ND	ND	ND	ND
Toluene	EPA 8240	5	ND	ND	ND	ND
Chlorobenzene	EPA 8240	5	<sup>b</sup>	ND	ND	ND

<sup>a</sup> Results expressed as µg/L.<sup>b</sup> Detected below quantitation level.

TABLE A48-2. (CONTINUED) - BASE/NEUTRAL COMPOUNDS<sup>a</sup>

Parameter	Method	Detection Limits	100% G.W.	10% G.W.	1% G.W.	Diluent H <sub>2</sub> O
Acenaphthene	EPA 8270	10	ND	ND	ND	ND
2,4-Dinitrotoluene	EPA 8270	10	ND	ND	ND	ND
2,6-Dinitrotoluene	EPA 8270	10	ND	ND	ND	ND
Diethyl phthalate	EPA 8270	10	ND	ND	ND	ND
4-Chlorophenyl phenyl ether	EPA 8270	10	ND	ND	ND	ND
Fluorene	EPA 8270	10	ND	ND	ND	ND
N-Nitrosodiphenylamine	EPA 8270	10	ND	ND	ND	ND
1,2-Diphenylhydrazine	EPA 8270	10	ND	ND	ND	ND
4-Bromophenyl phenyl ether	EPA 8270	10	ND	ND	ND	ND
Hexachlorobenzene	EPA 8270	10	ND	ND	ND	ND
Phenanthrene	EPA 8270	10	ND	ND	ND	ND
Anthracene	EPA 8270	10	ND	ND	ND	ND
Di-n-butyl phthalate	EPA 8270	10	ND	ND	ND	ND
Fluoranthene	EPA 8270	10	ND	ND	ND	ND
Pyrene	EPA 8270	10	ND	ND	ND	ND
Benzidine	EPA 8270	50	ND	ND	ND	ND
Butylbenzyl phthalate	EPA 8270	10	ND	ND	ND	ND
3,3'-Dichlorobenzidine	EPA 8270	20	ND	ND	ND	ND
Benzo(a)anthracene	EPA 8270	10	ND	ND	ND	ND
bis(2-Ethylhexyl) phthalate	EPA 8270	10	ND	ND	ND	ND
Chrysene	EPA 8270	10	ND	ND	ND	ND
Di-n-octyl phthalate	EPA 8270	10	ND	ND	ND	ND
Benzo(b)fluoranthene	EPA 8270	10	ND	ND	ND	ND
Benzo(k)fluoranthene	EPA 8270	10	ND	ND	ND	ND
Benzo(a)pyrene	EPA 8270	10	ND	ND	ND	ND
Indeno(1,2,3-cd)pyrene	EPA 8270	10	ND	ND	ND	ND
Dibenz(a,h)anthracene	EPA 8270	10	ND	ND	ND	ND
Benzo(g,h,i)perylene	EPA 8270	10	ND	ND	ND	ND

<sup>a</sup> Results expressed as µg/L.

TABLE A48-2. (CONTINUED) - BASE/NEUTRAL COMPOUNDS CON'T<sup>a</sup>

Parameter	Method	Detection Limits	100% G.W.	10% G.W.	1% G.W.	Diluent H <sub>2</sub> O
N-Nitrosodimethylamine	EPA 8270	10	ND	ND	ND	ND
bis(2-Chloroethyl) ether	EPA 8270	10	ND	ND	ND	ND
1,3-Dichlorobenzene	EPA 8270	10	ND	ND	ND	ND
1,4-Dichlorobenzene	EPA 8270	10	ND	ND	ND	ND
1,2-Dichlorobenzene	EPA 8270	10	ND	ND	ND	ND
bis(2-Chloroisopropyl) ether	EPA 8270	10	ND	ND	ND	ND
N-Nitrosodi-n-propylamine	EPA 8270	10	ND	ND	ND	ND
Hexachloroethane	EPA 8270	10	ND	ND	ND	ND
Nitrobenzene	EPA 8270	10	ND	ND	ND	ND
Isophorone	EPA 8270	10	ND	ND	ND	ND
bis(2-Chloroethoxy)methane	EPA 8270	10	ND	ND	ND	ND
1,2,4-Trichlorobenzene	EPA 8270	10	ND	ND	ND	ND
Naphthalene	EPA 8270	10	ND	ND	ND	ND
Hexachlorobutadiene	EPA 8270	10	ND	ND	ND	ND
Hexachlorocyclopentadiene	EPA 8270	10	ND	ND	ND	ND
2-Chloronaphthalene	EPA 8270	10	ND	ND	ND	ND
Dimethyl phthalate	EPA 8270	10	ND	ND	ND	ND
Acenaphthylene	EPA 8270	10	ND	ND	ND	ND

<sup>a</sup> Results expressed as µg/L.

TABLE A48-2. (CONTINUED) - PESTICIDES<sup>a</sup>

Parameter	Method	Detection Limits	100% G.W.	10% G.W.	1% G.W.	Diluent H <sub>2</sub> O
a-BHC	EPA 8080	0.05	ND	ND	ND	ND
b-BHC	EPA 8080	0.05	ND	ND	ND	ND
g-BHC	EPA 8080	0.05	ND	ND	ND	ND
d-BHC	EPA 8080	0.05	ND	ND	ND	ND
Heptachlor	EPA 8080	0.05	ND	ND	ND	ND
Aldrin	EPA 8080	0.05	ND	ND	ND	ND
Heptachlor epoxide	EPA 8080	0.05	ND	ND	ND	ND
a-Endosulfan	EPA 8080	0.05	ND	ND	ND	ND
4,4'-DDE	EPA 8080	0.1	ND	ND	ND	ND
Dieldrin	EPA 8080	0.1	ND	ND	ND	ND
Endrin	EPA 8080	0.1	ND	ND	ND	ND
b-Endosulfan	EPA 8080	0.3	ND	ND	ND	ND
Endrin aldehyde	EPA 8080	0.3	ND	ND	ND	ND
4,4'-DDD	EPA 8080	0.3	ND	ND	ND	ND
Endosulfan sulfate	EPA 8080	0.3	ND	ND	ND	ND
4,4'-DDT	EPA 8080	0.3	ND	ND	ND	ND
PCB-1242	EPA 8080	1	ND	ND	ND	ND
PCB-1254	EPA 8080	1	ND	ND	ND	ND
PCB-1221	EPA 8080	1	ND	ND	ND	ND
PCB-1232	EPA 8080	1	ND	ND	ND	ND
PCB-1248	EPA 8080	1	ND	ND	ND	ND
PCB-1260	EPA 8080	1	ND	ND	ND	ND
PCB-1016	EPA 8080	1	ND	ND	ND	ND
Chlordane	EPA 8080	1	ND	ND	ND	ND
Toxaphene	EPA 8080	3	ND	ND	ND	ND

<sup>a</sup> Results expressed as µg/L.



TABLE A48-2. (CONTINUED) - HERBICIDES AND ORGANOPHOSPHORUS PESTICIDES<sup>a</sup>

Parameter	Method	Detection Limits	100% G.W.	10% G.W.	1% G.W.	Diluent H <sub>2</sub> O
<u>Herbicides:</u>						
2,4-D	EPA 8150	0.5	ND	ND	ND	ND
2,4,5-TP (Silvex)	EPA 8150	0.2	ND	ND	ND	ND
<u>Organophosphorus Pesticides:</u>						
Malathion	EPA 8080	0.5	ND	ND	ND	ND
Methyl azinphos	EPA 8080	3	ND	ND	ND	ND
Coumaphos	EPA 8080	2	ND	ND	ND	ND
Chlorpyrifos	EPA 8080	0.1	ND	ND	ND	ND
Diazinon	EPA 8080	0.5	ND	ND	ND	ND
Fenthion	EPA 8080	50	ND	ND	ND	ND
Naled	EPA 8080	5	ND	ND	ND	ND
Methyl parathion	EPA 8080	0.5	ND	ND	ND	ND
Parathion	EPA 8080	0.5	ND	ND	ND	ND

<sup>a</sup> Results expressed as µg/L.

TABLE A48-2. (CONTINUED) - ACID COMPOUNDS<sup>a</sup>

Parameter	Method	Detection Limits	100% G.W.	10% G.W.	1% G.W.	Diluent H <sub>2</sub> O
Phenol	EPA 8270	10	ND	ND	ND	ND
2-Chlorophenol	EPA 8270	10	ND	ND	ND	ND
2-Nitrophenol	EPA 8270	10	ND	ND	ND	ND
2,4-Dimethylphenol	EPA 8270	10	ND	ND	ND	ND
2,4-Dichlorophenol	EPA 8270	10	ND	ND	ND	ND
4-Chloro-3-methylphenol	EPA 8270	20	ND	ND	ND	ND
2,4,6-Trichlorophenol	EPA 8270	10	ND	ND	ND	ND
2,4-Dinitrophenol	EPA 8270	50	ND	ND	ND	ND
4-Nitrophenol	EPA 8270	50	ND	ND	ND	ND
4,6-Dinitro-2-methylphenol	EPA 8270	50	ND	ND	ND	ND
Pentachlorophenol	EPA 8270	50	ND	ND	ND	ND

<sup>a</sup> Results expressed as µg/L.

TABLE A48-3. RESULTS OF THE APG-EA BEACH POINT GROUNDWATER AND DILUENT WATER  
COMPREHENSIVE CHEMICAL ANALYSES (TEST NO. 3) - GENERAL WATER QUALITY<sup>a</sup>

Parameter	Method	Detection Limits	100% G.W.	10% G.W.	1% G.W.	Diluent H <sub>2</sub> O
Total Alkalinity (CaCO <sub>3</sub> )	EPA 310.1	1	ND	20	22	25
Ammonia (N)	SM 4500-NH <sub>3</sub> E	0.1	ND	ND	ND	ND
Chloride (Cl)	EPA 325.3	b	580	78	27	21
Total Cyanide (CN)	EPA 335.3	0.01	ND	ND	ND	ND
Fluoride (F)	EPA 340.2	0.05	0.24	0.88	0.98	0.94
Hardness, (CaCO <sub>3</sub> )	EPA 130.2	c	300	92	76	81
Nitrate (N)	EPA 353.2	0.1	ND	1.7	1.8	1.8
Nitrite (N)	EPA 354.1	0.01	ND	ND	ND	ND
Total Phosphorus (P)	EPA 365.2	0.01	0.01	0.39	0.44	0.43
Total Suspended Solids	EPA 160.2	5	ND	ND	ND	ND
Specific Conductance	EPA 120.1	N/A	1680	376	212	196
Sulfate (SO <sub>4</sub> )	EPA 375.4	1	75	21	16	17
Sulfide (S)	EPA 376.1	1	ND	ND	ND	ND
TOC	EPA 415.1	1	2	ND	ND	ND
Bromide (Br)	SM 4500-Br	0.1	0.83	0.26	ND	ND

<sup>a</sup> All results expressed as mg/L except for specific conductance which is expressed as  $\mu\text{mhos/cm}$ .

<sup>b</sup> The detection limit was 10 mg/L for the 100% groundwater sample and 1 mg/L for the 10% and 1% groundwater and dilution water samples.

<sup>c</sup> The detection limit was 5 mg/L for the 100% groundwater sample and 1 mg/L for the 10% and 1% groundwater and dilution water samples.

TABLE A48-3. (CONTINUED) - METALS<sup>a</sup>

Parameter	Method	Detection Limits	100% G.W.	10% G.W.	1% G.W.	Diluent H <sub>2</sub> O
Aluminum (Al)	EPA 200.7	0.1	1.3	0.1	ND	ND
Antimony (Sb)	EPA 204.2	0.005	ND	ND	ND	ND
Arsenic (As)	EPA 206.2	0.005	ND	ND	ND	ND
Beryllium (Be)	EPA 200.7	0.005	ND	ND	ND	ND
Boron (B)	EPA 200.7	0.05	0.05	ND	ND	ND
Cadmium (Cd)	EPA 213.2	0.0005	0.0014	ND	ND	ND
Calcium (Ca)	EPA 200.7	0.5	19	16	16	16
Chromium (Cr)	EPA 218.2	0.002	ND	ND	ND	ND
Cobalt (Co)	EPA 200.7	0.02	0.10	ND	ND	ND
Copper (Cu)	EPA 220.2	0.005	0.008	ND	ND	ND
Iron (Fe)	EPA 200.7	0.1	7.5	0.62	0.13	ND
Lead (Pb)	EPA 239.2	0.005	ND	ND	ND	ND
Magnesium (Mg)	EPA 200.7	0.5	37	7.7	4.1	4.2
Manganese (Mn)	EPA 200.7	0.01	2.1	0.22	0.02	ND
Mercury (Hg)	EPA 245.1	0.0005	ND	ND	ND	ND
Molybdenum (Mo)	EPA 200.7	0.02	ND	ND	ND	ND
Nickel (Ni)	EPA 200.7	0.02	0.16	0.02	0.06	0.03
Potassium (K)	EPA 200.7	0.5	3.1	2.5	1.7	2.0
Selenium (Se)	EPA 270.2	0.005	ND	ND	ND	ND
Silver (Ag)	EPA 272.2	0.001	ND	ND	ND	ND
Sodium (Na)	EPA 200.7	0.5	300	40	12	10
Thallium (Tl)	EPA 279.2	0.005	ND	ND	ND	ND
Tin (Sn)	EPA 282.2	0.005	ND	ND	ND	ND
Zinc (Zn)	EPA 200.7	0.05	0.30	0.44	0.45	0.47

<sup>a</sup> Results expressed as mg/L.

TABLE A48-3. (CONTINUED) - VOLATILES<sup>a</sup>

Parameter	Method	Detection Limits	100% G.W.	10% G.W.	1% G.W.	Diluent H <sub>2</sub> O
Chloromethane	EPA 8021	1	ND	ND	ND	ND
Bromomethane	EPA 8021	1	ND	ND	ND	ND
Vinyl chloride	EPA 8021	1	ND	ND	ND	ND
Chloroethane	EPA 8021	1	ND	ND	ND	ND
Methylene chloride	EPA 8021	1	ND	ND	ND	ND
Trichlorofluoromethane	EPA 8021	1	ND	ND	ND	ND
1,1-Dichloroethane	EPA 8021	1	ND	ND	ND	ND
1,2-Dichloroethene	EPA 8021	1	140	6	b	ND
Chloroform	EPA 8021	1	12	5	5	7
1,2-Dichloroethane	EPA 8021	1	ND	ND	ND	ND
1,1,1-Trichloroethane	EPA 8021	1	ND	ND	ND	ND
Carbon tetrachloride	EPA 8021	1	ND	ND	ND	ND
Bromodichloromethane	EPA 8021	1	ND	ND	ND	1
1,2-Dichloropropane	EPA 8021	1	ND	ND	ND	ND
1,3-Dichloropropene	EPA 8021	1	ND	ND	ND	ND
Dibromochloromethane	EPA 8021	1	ND	ND	ND	ND
1,1,2-Trichloroethane	EPA 8021	1	37	5	ND	ND
2-Chloroethylvinyl ether	EPA 8021	5	ND	ND	ND	ND
Bromoform	EPA 8021	2	ND	ND	ND	ND
Tetrachloroethene	EPA 8021	1	30	4	ND	ND
1,1,2,2-Tetrachloroethane	EPA 8021	c	10000	900	100	8
Ethylbenzene	EPA 8021	1	ND	ND	ND	ND
1,1-Dichloroethene	EPA 8021	1	ND	ND	ND	ND
Trichloroethene	EPA 8021	d	450	50	5	ND
Benzene	EPA 8021	1	ND	ND	ND	ND
Toluene	EPA 8021	1	ND	ND	ND	ND
Chlorobenzene	EPA 8021	1	2	ND	ND	ND

<sup>a</sup> Results expressed as µg/L.<sup>b</sup> Detected below quantitation level.<sup>c</sup> Detection limits were as follows: 1000 µg/L for the 100% groundwater sample, 100 µg/L for the 10% groundwater sample, 10 µg/L for the 1% groundwater sample, and 1 µg/L for the diluent water sample.<sup>d</sup> Detection limits were as follows: 20 µg/L for the 100% groundwater sample, 10 µg/L for the 10% groundwater sample, and 1 µg/L for the 1% groundwater and diluent water samples.

TABLE A48-3. (CONTINUED) - BASE/NEUTRAL COMPOUNDS<sup>a</sup>

Parameter	Method	Detection Limits	100% G.W.	10% G.W.	1% G.W.	Diluent H <sub>2</sub> O
Acenaphthene	EPA 8270	10	ND	ND	ND	ND
2,4-Dinitrotoluene	EPA 8270	10	ND	ND	ND	ND
2,6-Dinitrotoluene	EPA 8270	10	ND	ND	ND	ND
Diethyl phthalate	EPA 8270	10	ND	ND	ND	ND
4-Chlorophenyl phenyl ether	EPA 8270	10	ND	ND	ND	ND
Fluorene	EPA 8270	10	ND	ND	ND	ND
N-Nitrosodiphenylamine	EPA 8270	10	ND	ND	ND	ND
1,2-Diphenylhydrazine	EPA 8270	10	ND	ND	ND	ND
4-Bromophenyl phenyl ether	EPA 8270	10	ND	ND	ND	ND
Hexachlorobenzene	EPA 8270	10	ND	ND	ND	ND
Phenanthrene	EPA 8270	10	ND	ND	ND	ND
Anthracene	EPA 8270	10	ND	ND	ND	ND
Di-n-butyl phthalate	EPA 8270	10	ND	ND	ND	ND
Fluoranthene	EPA 8270	10	ND	ND	ND	ND
Pyrene	EPA 8270	10	ND	ND	ND	ND
Benzidine	EPA 8270	50	ND	ND	ND	ND
Butylbenzyl phthalate	EPA 8270	10	ND	ND	ND	ND
3,3'-Dichlorobenzidine	EPA 8270	20	ND	ND	ND	ND
Benzo(a)anthracene	EPA 8270	10	ND	ND	ND	ND
bis(2-Ethylhexyl) phthalate	EPA 8270	10	ND	ND	ND	ND
Chrysene	EPA 8270	10	ND	ND	ND	ND
Di-n-octyl phthalate	EPA 8270	10	ND	ND	ND	ND
Benzo(b)fluoranthene	EPA 8270	10	ND	ND	ND	ND
Benzo(k)fluoranthene	EPA 8270	10	ND	ND	ND	ND
Benzo(a)pyrene	EPA 8270	10	ND	ND	ND	ND
Indeno(1,2,3-cd)pyrene	EPA 8270	10	ND	ND	ND	ND
Dibenz(a,h)anthracene	EPA 8270	10	ND	ND	ND	ND
Benzo(g,h,i)perylene	EPA 8270	10	ND	ND	ND	ND

<sup>a</sup> Results expressed as µg/L.

TABLE A48-3. (CONTINUED) - BASE/NEUTRAL COMPOUNDS CON'T<sup>a</sup>

Parameter	Method	Detection Limits	100% G.W.	10% G.W.	1% G.W.	Diluent
N-Nitrosodimethylamine	EPA 8270	10	ND	ND	ND	ND
bis(2-Chloroethyl) ether	EPA 8270	10	ND	ND	ND	ND
1,3-Dichlorobenzene	EPA 8270	10	ND	ND	ND	ND
1,4-Dichlorobenzene	EPA 8270	10	ND	ND	ND	ND
1,2-Dichlorobenzene	EPA 8270	10	ND	ND	ND	ND
bis(2-Chloroisopropyl) ether	EPA 8270	10	ND	ND	ND	ND
N-Nitrosodi-n-propylamine	EPA 8270	10	ND	ND	ND	ND
Hexachloroethane	EPA 8270	10	ND	ND	ND	ND
Nitrobenzene	EPA 8270	10	ND	ND	ND	ND
Isophorone	EPA 8270	10	ND	ND	ND	ND
bis(2-Chloroethoxy)methane	EPA 8270	10	ND	ND	ND	ND
1,2,4-Trichlorobenzene	EPA 8270	10	ND	ND	ND	ND
Naphthalene	EPA 8270	10	ND	ND	ND	ND
Hexachlorobutadiene	EPA 8270	10	ND	ND	ND	ND
Hexachlorocyclopentadiene	EPA 8270	10	ND	ND	ND	ND
2-Chloronaphthalene	EPA 8270	10	ND	ND	ND	ND
Dimethyl phthalate	EPA 8270	10	ND	ND	ND	ND
Acenaphthylene	EPA 8270	10	ND	ND	ND	ND

<sup>a</sup> Results expressed as µg/L.

TABLE A48-3. (CONTINUED) - PESTICIDES<sup>a</sup>

Parameter	Method	Detection Limits	100% G.W.	10% G.W.	1% G.W.	Diluent H <sub>2</sub> O
a-BHC	EPA 8080	0.05	ND	ND	ND	ND
b-BHC	EPA 8080	0.05	ND	ND	ND	ND
g-BHC	EPA 8080	0.05	ND	ND	ND	ND
d-BHC	EPA 8080	0.05	ND	ND	ND	ND
Heptachlor	EPA 8080	0.05	ND	ND	ND	ND
Aldrin	EPA 8080	0.05	ND	ND	ND	ND
Heptachlor epoxide	EPA 8080	0.05	ND	ND	ND	ND
a-Endosulfan	EPA 8080	0.1	ND	ND	ND	ND
4,4'-DDE	EPA 8080	0.1	ND	ND	ND	ND
Dieldrin	EPA 8080	0.1	ND	ND	ND	ND
Endrin	EPA 8080	0.1	ND	ND	ND	ND
b-Endosulfan	EPA 8080	0.3	ND	ND	ND	ND
Endrin aldehyde	EPA 8080	0.3	ND	ND	ND	ND
4,4'-DDD	EPA 8080	0.3	ND	ND	ND	ND
Endosulfan sulfate	EPA 8080	0.3	ND	ND	ND	ND
4,4'-DDT	EPA 8080	0.3	ND	ND	ND	ND
PCB-1242	EPA 8080	1	ND	ND	ND	ND
PCB-1254	EPA 8080	1	ND	ND	ND	ND
PCB-1221	EPA 8080	1	ND	ND	ND	ND
PCB-1232	EPA 8080	1	ND	ND	ND	ND
PCB-1248	EPA 8080	1	ND	ND	ND	ND
PCB-1260	EPA 8080	1	ND	ND	ND	ND
PCB-1016	EPA 8080	1	ND	ND	ND	ND
Chlordane	EPA 8080	1	ND	ND	ND	ND
Toxaphene	EPA 8080	3	ND	ND	ND	ND

<sup>a</sup> Results expressed as µg/L.



TABLE A48-3. (CONTINUED) - HERBICIDES AND ORGANOPHOSPHORUS PESTICIDES<sup>a</sup>

Parameter	Method	Detection Limits	100% G.W.	10% G.W.	1% G.W.	Diluent H <sub>2</sub> O
<u>Herbicides:</u>						
2,4-D	EPA 8150	0.5	ND	ND	ND	ND
2,4,5-TP (Silvex)	EPA 8150	0.2	ND	ND	ND	ND
<u>Organophosphorus Pesticides:</u>						
Malathion	EPA 8080	0.5	ND	ND	ND	ND
Methyl azinphos	EPA 8080	3	ND	ND	ND	ND
Coumaphos	EPA 8080	2	ND	ND	ND	ND
Chlorpyrifos	EPA 8080	0.1	ND	ND	ND	ND
Diazinon	EPA 8080	0.5	ND	ND	ND	ND
Fenthion	EPA 8080	50	ND	ND	ND	ND
Naled	EPA 8080	5	ND	ND	ND	ND
Methyl parathion	EPA 8080	0.5	ND	ND	ND	ND
Parathion	EPA 8080	0.5	ND	ND	ND	ND

<sup>a</sup> Results expressed as µg/L.

TABLE A48-3. (CONTINUED) - ACID COMPOUNDS<sup>a</sup>

Parameter	Method	Detection Limits	100% G.W.	10% G.W.	1% G.W.	Diluent H <sub>2</sub> O
Phenol	EPA 8270	10	ND	ND	ND	ND
2-Chlorophenol	EPA 8270	10	ND	ND	ND	ND
2-Nitrophenol	EPA 8270	10	ND	ND	ND	ND
2,4-Dimethylphenol	EPA 8270	10	ND	ND	ND	ND
2,4-Dichlorophenol	EPA 8270	10	ND	ND	ND	ND
4-Chloro-3-methylphenol	EPA 8270	20	ND	ND	ND	ND
2,4,6-Trichlorophenol	EPA 8270	10	ND	ND	ND	ND
2,4-Dinitrophenol	EPA 8270	50	ND	ND	ND	ND
4-Nitrophenol	EPA 8270	50	ND	ND	ND	ND
4,6-Dinitro-2-methylphenol	EPA 8270	50	ND	ND	ND	ND
Pentachlorophenol	EPA 8270	50	ND	ND	ND	ND

<sup>a</sup> Results expressed as µg/L.

TABLE A48-4. RESULTS OF THE APG-EA BEACH POINT GROUNDWATER AND DILUENT WATER COMPREHENSIVE CHEMICAL ANALYSES (TEST NO. 4) - GENERAL WATER QUALITY<sup>a</sup>

Parameter	Method	Detection Limits	100% G.W.	10% G.W.	1% G.W.	Diluent H <sub>2</sub> O
Total Alkalinity (CaCO <sub>3</sub> )	EPA 310.1	1	ND	18	23	21
Ammonia (N)	SM 4500-NH <sub>3</sub> E	0.1	ND	ND	ND	ND
Chloride (Cl)	EPA 325.3	<sup>b</sup>	570	72	25	19
Total Cyanide (CN)	EPA 335.3	0.01	ND	ND	ND	ND
Fluoride (F)	EPA 340.2	0.1	0.2	0.6	0.7	0.7
Hardness, (CaCO <sub>3</sub> )	EPA 130.2	<sup>c</sup>	230	89	68	76
Nitrate (N)	EPA 353.2	0.1	ND	1.9	2.1	2.2
Nitrite (N)	EPA 354.1	0.01	ND	ND	ND	ND
Total Phosphorus (P)	EPA 365.2	0.01	ND	0.32	0.36	0.37
Total Suspended Solids	EPA 160.2	5	ND	ND	ND	ND
Specific Conductance	EPA 120.1	N/A	2020	388	210	180
Sulfate (SO <sub>4</sub> )	EPA 375.4	<sup>c</sup>	82	29	22	19
Sulfide (S)	EPA 376.1	1	ND	ND	ND	ND
TOC	EPA 415.1	1	3	ND	ND	ND
Bromide (Br)	SM 4500-Br	0.1	0.4	0.3	0.1	ND

<sup>a</sup> All results expressed as mg/L except for specific conductance which is expressed as  $\mu\text{mhos/cm}$ .

<sup>b</sup> The detection limit was 10 mg/L for the 100% groundwater sample and 1 mg/L for the 10% and 1% groundwater and dilution water samples.

<sup>c</sup> The detection limit was 2 mg/L for the 100% groundwater sample and 1 mg/L for the 10% and 1% groundwater and dilution water samples.

TABLE 48-4. (CONTINUED) - METALS<sup>a</sup>

Parameter	Method	Detection Limits	100% G.W.	10% G.W.	1% G.W.	Diluent H <sub>2</sub> O
Aluminum (Al)	EPA 200.7	0.1	1.5	0.3	ND	ND
Antimony (Sb)	EPA 204.2	0.005	ND	ND	ND	ND
Arsenic (As)	EPA 206.2	0.005	0.007	ND	ND	ND
Beryllium (Be)	EPA 200.7	0.005	ND	ND	ND	ND
Boron (B)	EPA 200.7	0.05	0.07	ND	ND	ND
Cadmium (Cd)	EPA 213.2	0.0005	0.0009	ND	ND	ND
Calcium (Ca)	EPA 200.7	0.5	21	19	17	17
Chromium (Cr)	EPA 218.2	0.002	ND	ND	ND	ND
Cobalt (Co)	EPA 200.7	0.05	0.08	ND	ND	ND
Copper (Cu)	EPA 220.2	0.005	0.006	ND	ND	ND
Iron (Fe)	EPA 200.7	0.1	7.7	0.8	0.3	ND
Lead (Pb)	EPA 239.2	0.005	ND	ND	ND	ND
Magnesium (Mg)	EPA 200.7	0.5	43	9.9	6.1	5.5
Manganese (Mn)	EPA 200.7	0.01	2.1	0.22	0.03	ND
Mercury (Hg)	EPA 245.1	0.0005	ND	ND	ND	ND
Molybdenum (Mo)	EPA 200.7	0.05	ND	ND	ND	ND
Nickel (Ni)	EPA 200.7	0.05	0.18	ND	ND	ND
Potassium (K)	EPA 200.7	0.5	3.9	2.9	2.9	2.7
Selenium (Se)	EPA 270.2	0.005	ND	ND	ND	ND
Silver (Ag)	EPA 272.2	0.001	ND	ND	ND	ND
Sodium (Na)	EPA 200.7	0.5	350	41	13	9.1
Thallium (Tl)	EPA 279.2	0.005	ND	ND	ND	ND
Tin (Sn)	EPA 282.2	0.005	ND	ND	ND	ND
Zinc (Zn)	EPA 200.7	0.05	0.31	0.62	0.66	0.60

<sup>a</sup> Results expressed as mg/L.

TABLE 48-4. (CONTINUED) - VOLATILES<sup>a</sup>

Parameter	Method	Detection Limits	100% G.W.	10% G.W.	1% G.W.	Diluent H <sub>2</sub> O
Chloromethane	EPA 8021	2	ND	ND	ND	ND
Bromomethane	EPA 8021	5	ND	ND	ND	ND
Vinyl chloride	EPA 8021	2	ND	ND	ND	ND
Chloroethane	EPA 8021	1	ND	ND	ND	ND
Methylene chloride	EPA 8021	1	ND	ND	ND	ND
Trichlorofluoromethane	EPA 8021	1	ND	ND	ND	ND
1,1-Dichloroethane	EPA 8021	1	ND	ND	ND	ND
1,2-Dichloroethene	EPA 8021	1	110	4	ND	ND
Chloroform	EPA 8021	1	12	4	3	3
1,2-Dichloroethane	EPA 8021	1	ND	ND	ND	ND
1,1,1-Trichloroethane	EPA 8021	1	ND	ND	ND	ND
Carbon tetrachloride	EPA 8021	1	ND	ND	ND	ND
Bromodichloromethane	EPA 8021	1	ND	ND	ND	ND
1,2-Dichloropropane	EPA 8021	1	ND	ND	ND	ND
1,3-Dichloropropene	EPA 8021	1	ND	ND	ND	ND
Dibromochloromethane	EPA 8021	1	ND	ND	ND	ND
1,1,2-Trichloroethane	EPA 8021	1	70	4	ND	ND
2-Chloroethylvinyl ether	EPA 8021	5	ND	ND	ND	ND
Bromoform	EPA 8021	5	ND	ND	ND	ND
Tetrachloroethene	EPA 8021	1	80	3	ND	ND
1,1,2,2-Tetrachloroethane	EPA 8021	b	9000	700	91	4
Ethylbenzene	EPA 8021	1	ND	ND	ND	ND
1,1-Dichloroethene	EPA 8021	1	ND	ND	ND	ND
Trichloroethene	EPA 8021	1	780	40	4	ND
Benzene	EPA 8021	1	ND	ND	ND	ND
Toluene	EPA 8021	1	ND	ND	ND	ND
Chlorobenzene	EPA 8021	1	ND	ND	ND	ND

<sup>a</sup> Results expressed as  $\mu\text{g/L}$ .<sup>b</sup> The detection limit was 10  $\mu\text{g/L}$  for the 100% groundwater sample and 1  $\mu\text{g/L}$  for the 10% and 1% groundwater and diluent water samples.

TABLE A48-4. (CONTINUED) - BASE/NEUTRAL COMPOUNDS<sup>a</sup>

Parameter	Method	Detection Limits	100% G.W.	10% G.W.	1% G.W.	Diluent H <sub>2</sub> O
Acenaphthene	EPA 8270A	10	ND	ND	ND	ND
2,4-Dinitrotoluene	EPA 8270A	10	ND	ND	ND	ND
2,6-Dinitrotoluene	EPA 8270A	10	ND	ND	ND	ND
Diethyl phthalate	EPA 8270A	10	ND	ND	ND	ND
4-Chlorophenyl phenyl ether	EPA 8270A	10	ND	ND	ND	ND
Fluorene	EPA 8270A	10	ND	ND	ND	ND
N-Nitrosodiphenylamine	EPA 8270A	10	ND	ND	ND	ND
1,2-Diphenylhydrazine	EPA 8270A	10	ND	ND	ND	ND
4-Bromophenyl phenyl ether	EPA 8270A	10	ND	ND	ND	ND
Hexachlorobenzene	EPA 8270A	10	ND	ND	ND	ND
Phenanthrene	EPA 8270A	10	ND	ND	ND	ND
Anthracene	EPA 8270A	10	ND	ND	ND	ND
Di-n-butyl phthalate	EPA 8270A	10	ND	ND	ND	ND
Fluoranthene	EPA 8270A	10	ND	ND	ND	ND
Pyrene	EPA 8270A	10	ND	ND	ND	ND
Benzidine	EPA 8270A	10	ND	ND	ND	ND
Butylbenzyl phthalate	EPA 8270A	50	ND	ND	ND	ND
3,3'-Dichlorobenzidine	EPA 8270A	10	ND	ND	ND	ND
Benzo(a)anthracene	EPA 8270A	20	ND	ND	ND	ND
bis(2-Ethylhexyl) phthalate	EPA 8270A	10	ND	ND	ND	ND
Chrysene	EPA 8270A	10	ND	ND	ND	ND
Di-n-octyl phthalate	EPA 8270A	10	ND	ND	ND	ND
Benzo(b)fluoranthene	EPA 8270A	10	ND	ND	ND	ND
Benzo(k)fluoranthene	EPA 8270A	10	ND	ND	ND	ND
Benzo(a)pyrene	EPA 8270A	10	ND	ND	ND	ND
Indeno(1,2,3-cd)pyrene	EPA 8270A	10	ND	ND	ND	ND
Dibenz(a,h)anthracene	EPA 8270A	10	ND	ND	ND	ND
Benzo(g,h,i)perylene	EPA 8270A	10	ND	ND	ND	ND

<sup>a</sup> Results expressed as µg/L.

TABLE A48-4. (CONTINUED) - BASE/NEUTRAL COMPOUNDS CON'T<sup>a</sup>

Parameter	Method	Detection Limits	100% G.W.	10% G.W.	1% G.W.	Diluent H <sub>2</sub> O
N-Nitrosodimethylamine	EPA 8270A	10	ND	ND	ND	ND
bis(2-Chloroethyl) ether	EPA 8270A	10	ND	ND	ND	ND
1,3-Dichlorobenzene	EPA 8270A	10	ND	ND	ND	ND
1,4-Dichlorobenzene	EPA 8270A	10	ND	ND	ND	ND
1,2-Dichlorobenzene	EPA 8270A	10	ND	ND	ND	ND
bis(2-Chloroisopropyl) ether	EPA 8270A	10	ND	ND	ND	ND
N-Nitrosodi-n-propylamine	EPA 8270A	10	ND	ND	ND	ND
Hexachloroethane	EPA 8270A	10	ND	ND	ND	ND
Nitrobenzene	EPA 8270A	10	ND	ND	ND	ND
Isophorone	EPA 8270A	10	ND	ND	ND	ND
bis(2-Chloroethoxy)methane	EPA 8270A	10	ND	ND	ND	ND
1,2,4-Trichlorobenzene	EPA 8270A	10	ND	ND	ND	ND
Naphthalene	EPA 8270A	10	ND	ND	ND	ND
Hexachlorobutadiene	EPA 8270A	10	ND	ND	ND	ND
Hexachlorocyclopentadiene	EPA 8270A	10	ND	ND	ND	ND
2-Chloronaphthalene	EPA 8270A	10	ND	ND	ND	ND
Dimethyl phthalate	EPA 8270A	10	ND	ND	ND	ND
Acenaphthylene	EPA 8270A	10	ND	ND	ND	ND

<sup>a</sup> Results expressed as µg/L.

TABLE A48-4. (CONTINUED) - PESTICIDES<sup>a</sup>

Parameter	Method	Detection Limits	100% G.W.	10% G.W.	1% G.W.	Diluent H <sub>2</sub> O
a-BHC	EPA 8080	0.05	ND	ND	ND	ND
b-BHC	EPA 8080	0.05	ND	ND	ND	ND
g-BHC	EPA 8080	0.05	ND	ND	ND	ND
d-BHC	EPA 8080	0.05	ND	ND	ND	ND
Heptachlor	EPA 8080	0.05	ND	ND	ND	ND
Aldrin	EPA 8080	0.05	ND	ND	ND	ND
Heptachlor epoxide	EPA 8080	0.05	ND	ND	ND	ND
a-Endosulfan	EPA 8080	0.1	ND	ND	ND	ND
4,4'-DDE	EPA 8080	0.1	ND	ND	ND	ND
Dieldrin	EPA 8080	0.1	ND	ND	ND	ND
Endrin	EPA 8080	0.1	ND	ND	ND	ND
b-Endosulfan	EPA 8080	0.3	ND	ND	ND	ND
Endrin aldehyde	EPA 8080	0.3	ND	ND	ND	ND
4,4'-DDD	EPA 8080	0.3	ND	ND	ND	ND
Endosulfan sulfate	EPA 8080	0.3	ND	ND	ND	ND
4,4'-DDT	EPA 8080	0.3	ND	ND	ND	ND
PCB-1242	EPA 8080	1	ND	ND	ND	ND
PCB-1254	EPA 8080	1	ND	ND	ND	ND
PCB-1221	EPA 8080	1	ND	ND	ND	ND
PCB-1232	EPA 8080	1	ND	ND	ND	ND
PCB-1248	EPA 8080	1	ND	ND	ND	ND
PCB-1260	EPA 8080	1	ND	ND	ND	ND
PCB-1016	EPA 8080	1	ND	ND	ND	ND
Chlordane	EPA 8080	1	ND	ND	ND	ND
Toxaphene	EPA 8080	3	ND	ND	ND	ND

<sup>a</sup> Results expressed as µg/L.



TABLE A48-4. (CONTINUED) - HERBICIDES AND ORGANOPHOSPHORUS PESTICIDES<sup>a</sup>

Parameter	Method	Detection Limits	100% G.W.	10% G.W.	1% G.W.	Diluent H <sub>2</sub> O
<u>Herbicides:</u>						
2,4-D	EPA 8150A	0.5	ND	ND	ND	ND
2,4,5-TP (Silvex)	EPA 8150A	0.2	ND	ND	ND	ND
<u>Organophosphorus Pesticides:</u>						
Malathion	EPA 8080	0.5	ND	ND	ND	ND
Methyl azinphos	EPA 8080	3	ND	ND	ND	ND
Coumaphos	EPA 8080	2	ND	ND	ND	ND
Chlorpyrifos	EPA 8080	0.1	ND	ND	ND	ND
Diazinon	EPA 8080	0.5	ND	ND	ND	ND
Fenthion	EPA 8080	50	ND	ND	ND	ND
Naled	EPA 8080	5	ND	ND	ND	ND
Methyl parathion	EPA 8080	0.5	ND	ND	ND	ND
Parathion	EPA 8080	0.5	ND	ND	ND	ND

<sup>a</sup> Results expressed as µg/L.

TABLE A48-4. (CONTINUED) - ACID COMPOUNDS<sup>a</sup>

Parameter	Method	Detection Limits	100% G.W.	10% G.W.	1% G.W.	Diluent H <sub>2</sub> O
Phenol	EPA 8270A	10	ND	ND	ND	ND
2-Chlorophenol	EPA 8270A	10	ND	ND	ND	ND
2-Nitrophenol	EPA 8270A	10	ND	ND	ND	ND
2,4-Dimethylphenol	EPA 8270A	10	ND	ND	ND	ND
2,4-Dichlorophenol	EPA 8270A	10	ND	ND	ND	ND
4-Chloro-3-methylphenol	EPA 8270A	20	ND	ND	ND	ND
2,4,6-Trichlorophenol	EPA 8270A	10	ND	ND	ND	ND
2,4-Dinitrophenol	EPA 8270A	50	ND	ND	ND	ND
4-Nitrophenol	EPA 8270A	50	ND	ND	ND	ND
4,6-Dinitro-2-methylphenol	EPA 8270A	50	ND	ND	ND	ND
Pentachlorophenol	EPA 8270A	50	ND	ND	ND	ND

<sup>a</sup> Results expressed as  $\mu\text{g/L}$ .

APPENDIX 49

ROUTINE WATER QUALITY OF THE CHRONIC  
HISTOPATHOLOGY EXPOSURE TANKS

TANK No. 1  
TANK CONCENTRATION: 100% DILUENT WATER  
NO DEN EXPOSURE

Date	Test Day	Time (Military)	Temperature (Celsius)	pH	Dissolved Oxygen (mg/L)	Alkalinity (mg/L as CaCO3)	Hardness (mg/L as CaCO3)	Conductivity (umohs/cm)	Total Residual Chlorine (mg/L)	Free Available Chlorine (mg/L)	Total Ammonia- Nitrogen (mg/L)	Total Unionized Ammonia- Nitrogen (mg/L)
02-25-93	1	1500	24.8	6.63	7.60							
02-26-93	2	1000	24.1	7.17	7.66							
02-27-93	3	1000	24.5	7.11	7.59							
02-28-93	4	1100	24.6	7.09	7.54	34.0	85.5					
03-01-93	5	930	24.9	7.09	7.32							
03-02-93	6	1000	25.5	7.05	7.13							
03-03-93	7	1000	26.0	7.32	7.66							
03-04-93	8	1000	25.2	7.45	7.74							
03-05-93	9	800	25.5	7.43	7.49							
03-06-93	10	1000	24.9	7.28	7.81	34.0	85.5	294				
03-07-93	11	1100	25.0	7.07	7.80							
03-08-93	12	900	25.0	7.06	7.73							
03-09-93	13	930	25.3	7.19	7.58							
03-10-93	14	900	24.9	7.07	7.73							
03-11-93	15	900	25.2	7.46	7.62							
03-12-93	16	800	24.6	7.41	8.10			194	0.00	0.00		
03-13-93	17	1600	24.8	7.18	7.86							
03-14-93	18	1500	24.9	7.82	7.82							
03-15-93	19	900	24.7	7.11	7.97							
03-16-93	20	900	25.3	7.21	7.80							
03-17-93	21	900	25.5	7.22	7.43	34.0	85.5	411	0.00	0.00	0.019	0.00018
03-18-93	22	1030	25.3	7.05	7.85							
03-19-93	23	1000	25.2	7.02	7.83							
03-20-93	24	1100	27.0	7.15	7.59							
03-21-93	25	1230	25.5	7.15	7.98							
03-22-93	26	900	25.0	7.22	8.00							
03-23-93	27	900	24.7	7.16	8.05							
03-24-93	28	900	25.3	7.05	7.86							
03-25-93	29	900	25.2	7.00	7.78	34.0	68.4	196	0.00	0.00	0.000	0.00000
03-26-93	30	800	24.9	7.21	8.09							
03-27-93	31	1000	25.4	7.24	7.76							
03-28-93	32	1000	25.7	7.36	7.64							
03-29-93	33	1100	25.9	7.37	7.73							
03-30-93	34	1100	25.6	7.24	7.68							
03-31-93	35	1000	25.6	7.36	6.30							
04-01-93	36	1000	24.9	7.45	8.01	40.8	68.4	189	0.00	0.00	0.000	0.00000
04-02-93	37	1000	24.9	7.40	8.08							
04-03-93	38	1100	24.9	7.42	8.23							
04-04-93	39	1300	24.7	7.40	8.39							
04-05-93	40	900	24.8	7.38	8.47							
04-06-93	41	1100	24.4	7.42	8.21							

04-07-93	42	900	25.0	7.49	8.34	40.8	85.5	189	0.00	0.00	0.00000
04-08-93	43	900	25.3	7.49	8.20						
04-09-93	44	900	25.3	7.50	7.97						
04-10-93	45	1000	25.7	7.46	7.82						
04-11-93	46	800	24.8	7.48	8.27						
04-12-93	47	1000	25.2	7.44	8.04						
04-13-93	48	900	25.0	7.48	7.87						
04-14-93	49	600	25.1	7.48	7.59	40.8	85.5	189	0.00	0.00	0.00051
04-15-93	50	900	25.3	7.47	7.59						
04-16-93	51	1000	25.7	7.46	8.53						
04-17-93	52	1000	25.3	7.47	7.67						
04-18-93	53	1000	24.8	7.50	7.83						
04-19-93	54	900	25.1	7.52	7.89						
04-20-93	55	900	25.5	7.46	7.81						
04-21-93	56	1000	25.7	7.48	7.61						
04-22-93	57	900	25.0	7.53	7.48	40.8	85.5	189	0.00	0.00	0.00000
04-23-93	58	900	24.9	7.51	7.48						
04-24-93	59	1000	25.1	7.48	7.96						
04-25-93	60	800	25.4	7.48	8.15						
04-26-93	61	900	25.4	7.43	7.42						
04-27-93	62	1000	24.4	7.54	8.06						
04-28-93	63	900	25.0	7.39	7.54						
04-29-93	64	1000	25.0	7.49	7.75	40.8	85.5	192	0.00	0.00	0.00035
04-30-93	65	1000	25.3	7.48	8.09						
05-01-93	66	1000	25.5	7.45	8.31						
05-02-93	67	1000	25.6	7.44	7.97						
05-03-93	68	1000	25.6	7.42	8.06						
05-04-93	69	1000	25.8	7.45	7.51						
05-05-93	70	900	25.7	7.39	7.49						
05-06-93	71	1000	25.2	7.40	7.44	40.8	85.5	198	0.00	0.00	0.00030
05-07-93	72	900	24.9	7.42	7.59						
05-08-93	73	1640	25.3	7.46	5.33						
05-09-93	74	1440	25.2	7.45	5.56						
05-10-93	75	1000	24.9	7.40	7.13						
05-11-93	76	900	25.2	7.45	7.70						
05-12-93	77	1000	25.3	7.40	7.11						
05-13-93	78	1000	25.2	7.44	7.20						
05-14-93	79	800	24.9	7.51	7.19	40.8	85.5	195	0.00	0.00	0.00000
05-15-93	80	800	25.0	7.49	7.56						
05-16-93	81	1100	25.2	7.47	7.76						
05-17-93	82	900	25.0	7.35	7.67						
05-18-93	83	1000	25.0	7.37	7.75						
05-19-93	84	1000	25.0	7.49	7.41						
05-20-93	85	900	25.2	7.45	7.23	40.8	102.6	204	0.00	0.00	0.00086
05-21-93	86	900	24.9	7.41	7.28						
05-22-93	87	800	24.7	7.56	7.52						
05-23-93	88	1000	24.6	7.46	7.41						
05-24-93	89	800	24.7	7.45	7.31						
05-25-93	90	1000	24.9	7.51	7.03						
05-26-93	91	900	24.9	7.54	7.41						
05-27-93	92	900	24.8	7.44	7.24						
05-28-93	93	1000	24.9	7.48	7.38	40.8	85.5	190	0.00	0.00	0.00085
05-29-93	94	1200	25.1	7.42	7.54						
05-30-93	95	900	24.9	7.44	6.96						





09-16-93	204	930	25.2	7.40	6.74	40.8	85.5	203	0.00	0.00	0.0000
09-17-93	205	930	24.6	7.30	6.73						
09-18-93	206	800	24.7	7.44	7.13						
09-19-93	207	1300	24.5	7.39	7.36						
09-20-93	208	930	24.4	7.36	7.33						
09-21-93	209	930	26.0	7.45	6.52						
09-22-93	210	900	25.3	7.27	6.79						
09-23-93	211	930	25.1	7.35	7.10	40.8	85.5	209	0.00	0.00	0.00000
09-24-93	212	1000	25.3	7.39	6.96						
09-25-93	213	900	25.1	7.39	7.25						
09-26-93	214	2100	25.7	7.52	7.37						
09-27-93	215	1000	25.5	7.44	7.01						
09-28-93	216	900	24.8	7.40	7.28						
09-29-93	217	930	24.7	7.41	7.28	40.8	85.5	209	0.00	0.008	0.00011
09-30-93	218	1300	24.6	7.23	7.24						
10-01-93	219	1100	24.1	7.32	8.73						
10-02-93	220	830	24.6	7.26	7.17						
10-03-93	221	830	24.7	7.28	7.05						
10-04-93	222	1000	24.4	7.35	7.37						
10-05-93	223	1000	24.9	7.37	7.13						
10-06-93	224	930	24.4	7.44	7.41						
10-07-93	225	930	24.9	7.48	7.23	47.6	85.5	206	0.00	0.000	0.00000
10-08-93	226	1000	25.0	7.40	7.27						
10-09-93	227	1130	24.7	7.46	7.31						
10-10-93	228	1130	24.7	7.46	7.49						
10-11-93	229	1600	24.6	7.47	7.48						
10-12-93	230	1000	24.5	7.37	7.42						
10-13-93	231	930	24.7	7.41	7.27						
10-14-93	232	1000	24.7	7.38	7.24	47.6	85.5	205	0.00	0.000	0.00000
10-15-93	233	1000	24.8	7.28	7.26						
10-16-93	234	1230	24.7	7.30	7.34						
10-17-93	235	1030	24.8	7.40	7.21						
10-18-93	236	1000	24.7	7.33	7.15						
10-19-93	237	900	24.8	7.29	7.19						
10-20-93	238	1000	24.8	7.38	7.41						
10-21-93	239	1000	24.8	7.39	7.20	47.6	85.5	206	0.00	0.012	0.00016
10-22-93	240	800	24.6	7.29	7.11						
10-23-93	241	700	24.3	7.23	7.57						
10-24-93	242	800	24.4	7.19	7.28						
10-25-93	243	1000	24.5	7.23	6.81						
10-26-93	244	1000	24.6	7.29	7.30						
10-27-93	245	1000	24.5	7.34	7.31						
10-28-93	246	1000	24.9	7.43	7.11	47.6	85.5	199	0.00	0.00	0.00018
10-29-93	247	1230	24.7	7.34	7.20						
10-30-93	248	700	25.1	7.41	7.18						
10-31-93	249	800	24.8	7.49	7.08						
11-01-93	250	930	24.5	7.31	7.08						
11-02-93	251	930	24.8	7.37	7.10						
11-03-93	252	1000	25.1	7.32	7.00						
11-04-93	253	1000	25.0	7.26	7.00	47.6	85.5	206	0.00	0.000	0.00000
11-05-93	254	1000	25.2	7.34	6.87						
11-06-93	255	600	25.3	7.22	6.84						
11-07-93	256	1000	25.0	7.28	6.73						
11-08-93	257	1000	24.8	7.28	6.94						





TANK No. 2  
TANK CONCENTRATION: 100% DILUENT WATER  
NO DEN EXPOSURE

Date	Test Day	Time (Military)	Temperature (Celsius)	pH	Dissolved Oxygen (mg/L)	Alkalinity (mg/L as CaCO3)	Hardness (mg/L as CaCO3)	Conductivity (umohs/cm)	Total Residual Chlorine (mg/L)	Free Available Chlorine (mg/L)	Total Ammonia- Nitrogen (mg/L)	Total Unionized Ammonia- Nitrogen (mg/L)
02-25-93	1	1500	24.8	6.68	7.60							
02-26-93	2	1000	24.2	7.16	7.59							
02-27-93	3	1000	24.5	7.11	7.54							
02-28-93	4	1100	24.7	7.09	7.32	34.0	85.5					
03-01-93	5	930	24.9	7.09	7.26							
03-02-93	6	1000	25.5	7.06	7.09							
03-03-93	7	1000	26.0	7.32	7.64							
03-04-93	8	1000	25.3	7.45	7.75							
03-05-93	9	800	25.5	7.42	7.52							
03-06-93	10	1000	24.9	7.28	7.79	34.0	85.5	291				
03-07-93	11	1100	25.0	7.09	7.75							
03-08-93	12	900	25.0	7.05	7.71							
03-09-93	13	930	25.3	7.19	7.61							
03-10-93	14	900	24.9	7.07	7.73							
03-11-93	15	900	25.2	7.46	7.64	54.4	85.5	196	0.00	0.00		
03-12-93	16	800	24.6	7.42	8.12							
03-13-93	17	1600	24.8	7.17	7.83							
03-14-93	18	1500	24.9	7.18	7.82							
03-15-93	19	900	24.7	7.11	8.04							
03-16-93	20	900	25.3	7.21	7.85							
03-17-93	21	900	25.5	7.23	7.48	34.0	85.5	408	0.00	0.00	0.017	0.00017
03-18-93	22	1030	25.3	7.05	7.86							
03-19-93	23	1000	25.2	7.02	7.75							
03-20-93	24	1100	27.0	7.15	7.67							
03-21-93	25	1230	25.5	7.15	8.04							
03-22-93	26	900	25.0	7.22	8.04							
03-23-93	27	900	24.7	7.16	8.05							
03-24-93	28	900	25.3	7.05	7.82							
03-25-93	29	900	25.2	7.00	7.81	34.0	68.4	195	0.00	0.00	0.0000	0.00000
03-26-93	30	800	24.9	7.21	8.09							
03-27-93	31	1000	25.4	7.24	7.74							
03-28-93	32	1000	25.7	7.36	7.72							
03-29-93	33	1100	25.9	7.37	7.78							
03-30-93	34	1100	25.6	7.28	7.73							
03-31-93	35	1000	25.6	7.36	6.29							
04-01-93	36	1000	24.9	7.47	8.12	40.8	68.4	188	0.00	0.00	0.0000	0.00000
04-02-93	37	1000	24.9	7.42	8.11							
04-03-93	38	1100	24.9	7.46	8.23							
04-04-93	39	1300	24.7	7.43	8.36							
04-05-93	40	900	24.8	7.40	8.34							
04-06-93	41	1100	24.4	7.44	8.23							

04-07-93	42	900	25.0	7.52	8.49	40.8	85.5	189	0.00	0.00	0.00000
04-08-93	43	900	25.3	7.51	8.25						
04-09-93	44	900	25.3	7.52	8.07						
04-10-93	45	1000	25.7	7.50	7.95						
04-11-93	46	800	24.8	7.50	8.43						
04-12-93	47	1000	25.2	7.47	8.16						
04-13-93	48	900	25.0	7.50	7.96						
04-14-93	49	600	25.1	7.50	7.65						
04-15-93	50	900	25.4	7.50	7.62	40.8	85.5	189	0.00	0.019	0.00035
04-16-93	51	1000	25.7	7.50	8.59						
04-17-93	52	1000	25.3	7.50	7.68						
04-18-93	53	1000	24.8	7.50	7.87						
04-19-93	54	900	25.1	7.52	7.89						
04-20-93	55	900	25.6	7.46	7.79						
04-21-93	56	1000	25.7	7.50	7.63						
04-22-93	57	900	25.0	7.53	7.63	40.8	85.5	188	0.00	0.000	0.00000
04-23-93	58	900	24.9	7.51	7.40						
04-24-93	59	1000	25.1	7.48	8.00						
04-25-93	60	800	25.4	7.48	8.14						
04-26-93	61	900	25.4	7.43	7.44						
04-27-93	62	1000	24.4	7.54	8.06						
04-28-93	63	900	25.0	7.40	7.58						
04-29-93	64	1000	25.0	7.49	7.76	40.8	85.5	193	0.00	0.017	0.00029
04-30-93	65	1000	25.3	7.48	7.95						
05-01-93	66	1000	25.5	7.45	8.18						
05-02-93	67	1000	25.6	7.44	7.94						
05-03-93	68	1000	25.6	7.42	7.94						
05-04-93	69	1000	25.8	7.45	7.45						
05-05-93	70	900	25.7	7.36	7.13						
05-06-93	71	1000	25.2	7.38	7.19	40.8	85.5	197	0.00	0.027	0.00037
05-07-93	72	900	24.9	7.42	7.41						
05-08-93	73	1640	25.3	7.39	5.40						
05-09-93	74	1440	25.2	7.44	5.22						
05-10-93	75	1000	24.9	7.40	7.04						
05-11-93	76	900	25.2	7.45	7.58						
05-12-93	77	1000	25.3	7.40	7.08						
05-13-93	78	1000	25.2	7.44	7.16	40.8	85.5	194	0.00	0.000	0.00000
05-14-93	79	800	24.9	7.51	7.15						
05-15-93	80	800	25.0	7.49	7.54						
05-16-93	81	1100	25.2	7.47	7.75						
05-17-93	82	900	25.0	7.36	7.64						
05-18-93	83	1000	25.0	7.37	7.75						
05-19-93	84	1000	25.0	7.49	7.40						
05-20-93	85	900	25.2	7.45	7.21	40.8	102.6	204	0.00	0.048	0.00077
05-21-93	86	900	25.0	7.42	7.26						
05-22-93	87	800	24.7	7.56	7.48						
05-23-93	88	1000	24.6	7.46	7.38						
05-24-93	89	800	24.8	7.45	7.27						
05-25-93	90	1000	24.9	7.51	7.01						
05-26-93	91	900	24.9	7.54	7.40						
05-27-93	92	900	24.8	7.44	7.21	40.8	85.5	190	0.00	0.053	0.00081
05-28-93	93	1000	24.9	7.48	7.38						
05-29-93	94	1200	25.1	7.42	7.44						
05-30-93	95	900	24.9	7.44	6.81						





09-16-93	204	930	25.2	7.40	6.71	40.8	85.5	203	0.00	0.00	0.00000
09-17-93	205	930	24.6	7.30	6.96						
09-18-93	206	930	24.7	7.44	7.01						
09-19-93	207	1300	24.6	7.39	7.30						
09-20-93	208	930	24.5	7.36	7.29						
09-21-93	209	930	26.0	7.45	6.52						
09-22-93	210	900	25.4	7.27	6.75						
09-23-93	211	930	25.1	7.35	6.91	40.8	85.5	209	0.00	0.00	0.00000
09-24-93	212	1000	25.3	7.39	6.74						
09-25-93	213	900	25.1	7.39	7.14						
09-26-93	214	2100	25.7	7.52	7.38						
09-27-93	215	1000	25.4	7.44	6.92						
09-28-93	216	900	24.8	7.40	7.19						
09-29-93	217	930	24.8	7.41	7.02	40.8	85.5	209	0.00	0.00	0.00014
09-30-93	218	1300	24.6	7.27	7.11						
10-01-93	219	1100	24.1	7.28	8.38						
10-02-93	220	830	24.7	7.30	7.18						
10-03-93	221	830	24.8	7.30	6.66						
10-04-93	222	1000	24.4	7.31	7.09						
10-05-93	223	1000	24.9	7.33	6.90						
10-06-93	224	930	24.4	7.42	7.26						
10-07-93	225	930	24.9	7.46	7.09	47.6	85.5	206	0.00	0.00	0.00000
10-08-93	226	1000	25.0	7.36	7.11						
10-09-93	227	1130	25.0	7.42	7.22						
10-10-93	228	1130	24.7	7.46	7.37						
10-11-93	229	1600	24.6	7.47	7.50						
10-12-93	230	1000	24.5	7.36	7.41						
10-13-93	231	930	24.7	7.41	7.27						
10-14-93	232	1000	24.7	7.36	7.16	47.6	85.5	205	0.00	0.00	0.00000
10-15-93	233	1000	24.8	7.27	7.23						
10-16-93	234	1230	24.7	7.28	7.16						
10-17-93	235	1030	24.8	7.40	7.16						
10-18-93	236	1000	24.7	7.33	7.15						
10-19-93	237	900	24.7	7.28	7.25						
10-20-93	238	1000	24.8	7.38	7.42						
10-21-93	239	1000	24.8	7.39	7.29						
10-22-93	240	800	24.6	7.27	7.01						
10-23-93	241	700	24.4	7.29	7.39						
10-24-93	242	800	24.4	7.18	7.21						
10-25-93	243	1000	24.4	7.27	6.73						
10-26-93	244	1000	24.6	7.32	7.32						
10-27-93	245	1000	24.4	7.34	7.36						
10-28-93	246	1000	24.9	7.43	7.09	47.6	85.5	199	0.00	0.00	0.00020
10-29-93	247	1230	24.7	7.34	7.16						
10-30-93	248	700	25.1	7.41	7.21						
10-31-93	249	800	24.7	7.49	7.14						
11-01-93	250	930	24.5	7.31	7.12						
11-02-93	251	930	24.8	7.37	7.13						
11-03-93	252	1000	25.1	7.32	7.01						
11-04-93	253	1000	25.0	7.26	7.03						
11-05-93	254	1000	25.2	7.34	6.89						
11-06-93	255	600	25.3	7.22	7.02						
11-07-93	256	1000	25.0	7.28	6.86						
11-08-93	257	1000	24.8	7.28	7.05						



TANK No. 3  
TANK CONCENTRATION: 100% DILUENT WATER  
DEN EXPOSURE: 10 mg/L

Date	Test Day	Time (Military)	Temperature (Celsius)	pH	Dissolved Oxygen (mg/L)	Alkalinity (mg/L as CaCO <sub>3</sub> )	Hardness (mg/L as CaCO <sub>3</sub> )	Conductivity (umohs/cm)	Total Residual Chlorine (mg/L)	Free Available Chlorine (mg/L)	Total Ammonia- Nitrogen (mg/L)	Total Unionized Ammonia- Nitrogen (mg/L)
02-25-93	1	1500	24.8	6.74	7.66							
02-26-93	2	1000	24.1	7.16	7.68							
02-27-93	3	1000	24.4	7.12	7.40							
02-28-93	4	1100	24.7	7.10	7.47	34.0	85.5					
03-01-93	5	930	25.0	7.09	7.24							
03-02-93	6	1000	25.5	7.05	7.09							
03-03-93	7	1000	26.0	7.32	7.78							
03-04-93	8	1000	25.2	7.45	7.68							
03-05-93	9	800	25.5	7.43	7.46							
03-06-93	10	1000	24.9	7.29	7.78	34.0	85.5	292				
03-07-93	11	1100	25.0	7.10	7.79							
03-08-93	12	900	25.0	7.05	7.64							
03-09-93	13	930	25.3	7.21	7.57							
03-10-93	14	900	24.9	7.08	7.65							
03-11-93	15	900	25.2	7.46	7.53				0.00	0.00		
03-12-93	16	800	24.5	7.42	8.03	54.4	85.5	194				
03-13-93	17	1600	24.8	7.17	7.78							
03-14-93	18	1500	24.9	7.17	7.75							
03-15-93	19	900	24.7	7.12	7.90							
03-16-93	20	900	25.3	7.23	7.78							
03-17-93	21	900	25.5	7.23	7.40	34.0	85.5	409	0.00	0.00	0.021	0.00021
03-18-93	22	1030	25.3	7.05	7.67							
03-19-93	23	1000	25.2	7.07	7.75							
03-20-93	24	1100	27.0	7.16	7.59							
03-21-93	25	1230	25.5	7.15	7.98							
03-22-93	26	900	25.0	7.22	7.93							
03-23-93	27	900	25.0	7.16	7.78							
03-24-93	28	900	25.3	7.05	7.73							
03-25-93	29	900	25.2	7.00	7.72	34.0	68.4	194	0.00	0.00	0.000	0.00000
03-26-93	30	800	24.9	7.21	8.04							
03-27-93	31	1000	25.4	7.24	7.71							
03-28-93	32	1000	25.7	7.36	7.60							
03-29-93	33	1100	25.9	7.37	7.64							
03-30-93	34	1100	25.6	7.30	7.72							
03-31-93	35	1000	25.6	7.36	6.08							
04-01-93	36	1000	24.8	7.45	7.97	40.8	68.4	188	0.00	0.00	0.000	0.00000
04-02-93	37	1000	24.9	7.41	7.97							
04-03-93	38	1100	24.9	7.44	8.01							
04-04-93	39	1300	24.8	7.42	8.18							
04-05-93	40	900	24.8	7.42	8.25							
04-06-93	41	1100	24.4	7.44	8.11							



04-07-93	42	900	24.9	7.50	8.35	40.8	85.5	189	0.00	0.00	0.00000
04-08-93	43	900	25.3	7.50	8.16						
04-09-93	44	900	25.3	7.52	8.01						
04-10-93	45	1000	25.7	7.47	7.85						
04-11-93	46	800	24.8	7.50	8.33						
04-12-93	47	1000	25.2	7.45	7.94						
04-13-93	48	900	25.0	7.50	7.83						
04-14-93	49	600	25.1	7.49	7.68						
04-15-93	50	900	25.4	7.47	7.51	40.8	85.5	188	0.00	0.024	0.00045
04-16-93	51	1000	25.7	7.48	8.42						
04-17-93	52	1000	25.3	7.47	7.55						
04-18-93	53	1000	24.8	7.51	7.71						
04-19-93	54	900	25.1	7.52	7.77						
04-20-93	55	900	25.6	7.46	7.63						
04-21-93	56	1000	25.7	7.48	7.48						
04-22-93	57	900	25.0	7.53	7.48	40.8	85.5	187	0.00	0.000	0.00000
04-23-93	58	900	24.9	7.51	7.29						
04-24-93	59	1000	25.1	7.48	7.79						
04-25-93	60	800	25.4	7.48	7.99						
04-26-93	61	900	25.4	7.43	7.40						
04-27-93	62	1000	24.4	7.54	7.97						
04-28-93	63	900	25.0	7.36	7.55						
04-29-93	64	1000	25.0	7.46	7.72	40.8	85.5	193	0.00	0.031	0.00050
04-30-93	65	1000	25.3	7.42	7.80						
05-01-93	66	1000	25.5	7.39	7.72						
05-02-93	67	1000	25.6	7.40	7.76						
05-03-93	68	1000	25.6	7.38	7.88						
05-04-93	69	1000	25.8	7.40	7.36						
05-05-93	70	900	25.7	7.33	7.12						
05-06-93	71	1000	25.2	7.33	7.03	40.8	85.5	198	0.00	0.032	0.00039
05-07-93	72	900	24.9	7.32	6.83						
05-08-93	73	1640	25.2	7.18	5.45						
05-09-93	74	1440	24.4	6.90	5.36						
05-10-93	75	1000	24.6	6.15	6.37						
05-11-93	76	900	25.2	7.44	7.43						
05-12-93	77	1000	25.3	7.41	6.96						
05-13-93	78	1000	25.2	7.44	6.98	40.8	85.5	194	0.00	0.000	0.00000
05-14-93	79	800	24.9	7.51	7.01						
05-15-93	80	800	25.1	7.48	7.36						
05-16-93	81	1100	25.3	7.47	7.58						
05-17-93	82	900	25.1	7.34	7.48						
05-18-93	83	1000	25.1	7.37	7.55						
05-19-93	84	1000	25.0	7.49	7.23						
05-20-93	85	900	25.2	7.43	6.94	40.8	85.5	203	0.00	0.058	0.00093
05-21-93	86	900	25.0	7.40	7.07						
05-22-93	87	800	24.7	7.53	7.26						
05-23-93	88	1000	24.6	7.45	7.20						
05-24-93	89	800	24.8	7.42	7.01						
05-25-93	90	1000	24.9	7.51	6.83						
05-26-93	91	900	24.9	7.54	7.31						
05-27-93	92	900	24.8	7.44	7.13	40.8	85.5	190	0.00	0.064	0.00097
05-28-93	93	1000	24.9	7.49	7.38						
05-29-93	94	1200	25.1	7.42	7.43						
05-30-93	95	900	24.9	7.45	6.94						



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09-16-93	204	930	25.2	7.40	6.73	40.8	85.5	203	0.00	0.00	0.00000
09-17-93	205	930	24.6	7.30	6.96						
09-18-93	206	800	24.7	7.44	7.09						
09-19-93	207	1300	24.5	7.39	7.47						
09-20-93	208	930	24.4	7.36	7.36						
09-21-93	209	930	26.0	7.45	6.86						
09-22-93	210	900	25.3	7.27	6.95						
09-23-93	211	930	25.1	7.35	7.14	40.8	85.5	208	0.00	0.00	0.00000
09-24-93	212	1000	25.3	7.39	7.00						
09-25-93	213	900	25.1	7.39	7.30						
09-26-93	214	2100	25.7	7.52	7.38						
09-27-93	215	1000	25.4	7.44	7.08						
09-28-93	216	900	24.8	7.40	7.24						
09-29-93	217	930	24.8	7.41	7.28	40.8	85.5	209	0.00	0.00	0.00000
09-30-93	218	1300	24.6	7.29	7.23						
10-01-93	219	1100	24.1	7.31	8.77						
10-02-93	220	830	24.7	7.34	7.21						
10-03-93	221	830	24.9	7.32	6.70						
10-04-93	222	1000	24.4	7.35	7.36						
10-05-93	223	1000	24.9	7.36	7.17						
10-06-93	224	930	24.5	7.44	7.41						
10-07-93	225	930	24.9	7.48	7.33	47.6	85.5	206	0.00	0.00	0.00000
10-08-93	226	1000	25.0	7.40	7.36						
10-09-93	227	1130	24.9	7.46	7.41						
10-10-93	228	1130	24.7	7.46	7.51						
10-11-93	229	1600	24.6	7.47	7.52						
10-12-93	230	1000	24.5	7.36	7.37						
10-13-93	231	930	24.7	7.41	7.29						
10-14-93	232	1000	24.6	7.38	7.31	47.6	85.5	205	0.00	0.00	0.00000
10-15-93	233	1000	24.7	7.27	7.37						
10-16-93	234	1230	24.7	7.31	7.37						
10-17-93	235	1030	24.8	7.40	7.21						
10-18-93	236	1000	24.7	7.33	7.24						
10-19-93	237	900	24.8	7.30	7.31						
10-20-93	238	1000	24.8	7.38	7.30						
10-21-93	239	1000	24.9	7.39	7.19						
10-22-93	240	800	24.7	7.28	6.93						
10-23-93	241	700	24.5	7.29	7.41						
10-24-93	242	800	24.5	7.20	7.30						
10-25-93	243	1000	24.5	7.27	6.54						
10-26-93	244	1000	24.7	7.29	7.10						
10-27-93	245	1000	24.5	7.34	7.21						
10-28-93	246	1000	25.0	7.43	6.99	47.6	85.5	199	0.00	0.00	0.00030
10-29-93	247	1230	24.8	7.34	6.93						
10-30-93	248	700	25.2	7.38	6.81						
10-31-93	249	800	24.8	7.49	7.00						
11-01-93	250	930	24.6	7.29	6.96						
11-02-93	251	930	24.8	7.37	7.32						
11-03-93	252	1000	25.1	7.34	7.17						
11-04-93	253	1000	24.9	7.26	7.14	47.6	85.5	205	0.00	0.00	0.00000
11-05-93	254	1000	25.2	7.34	7.06						
11-06-93	255	600	25.3	7.22	6.87						
11-07-93	256	1000	25.0	7.30	6.92						
11-08-93	257	1000	24.8	7.28	7.10						



TANK No. 4  
TANK CONCENTRATION: 100% DILUENT WATER  
DEN EXPOSURE: 10 mg/L

Date	Test Day	Time (Military)	Temperature (Celsius)	pH	Dissolved Oxygen (mg/L)	Alkalinity (mg/L as CaCO3)	Hardness (mg/L as CaCO3)	Conductivity (umohs/cm)	Total Residual Chlorine (mg/L)	Free Available Chlorine (mg/L)	Total Ammonia- Nitrogen (mg/L)	Total Unionized Ammonia- Nitrogen (mg/L)
02-25-93	1	1500	24.8	6.74	7.63							
02-26-93	2	1000	24.2	7.16	7.58							
02-27-93	3	1000	24.5	7.13	7.33							
02-28-93	4	1100	24.9	7.10	7.37	34.0	85.5					
03-01-93	5	930	25.0	7.09	7.12							
03-02-93	6	1000	25.6	7.05	7.06							
03-03-93	7	1000	26.0	7.32	7.78							
03-04-93	8	1000	25.3	7.45	7.68							
03-05-93	9	800	25.6	7.44	7.48							
03-06-93	10	1000	24.9	7.30	7.74	34.0	85.5	292				
03-07-93	11	1100	25.0	7.09	7.78							
03-08-93	12	900	25.0	7.06	7.67							
03-09-93	13	930	25.3	7.21	7.58							
03-10-93	14	900	25.0	7.08	7.65							
03-11-93	15	900	25.3	7.46	7.53				0.00	0.00		
03-12-93	16	800	24.6	7.41	8.02	54.4	85.5	193				
03-13-93	17	1600	24.8	7.18	7.77							
03-14-93	18	1500	24.7	7.12	7.94							
03-15-93	19	900	24.7	7.12	7.83							
03-16-93	20	900	25.3	7.23	7.46	34.0	85.5	409	0.00	0.00	0.020	0.00020
03-17-93	21	900	25.5	7.23	7.59							
03-18-93	22	1030	25.5	7.05	7.33							
03-19-93	23	1000	25.3	7.07	7.33							
03-20-93	24	1100	27.1	7.16	7.61							
03-21-93	25	1230	25.5	7.15	7.96							
03-22-93	26	900	25.0	7.22	7.94							
03-23-93	27	900	25.0	7.16	7.86							
03-24-93	28	900	25.3	7.05	7.79							
03-25-93	29	900	25.2	7.00	7.76	34.0	68.4	195	0.00	0.00	0.000	0.00000
03-26-93	30	800	24.9	7.21	8.03							
03-27-93	31	1000	25.4	7.24	7.70							
03-28-93	32	1000	25.7	7.36	7.61							
03-29-93	33	1100	25.9	7.37	7.63							
03-30-93	34	1100	25.6	7.24	7.72							
03-31-93	35	1000	25.6	7.36	6.06							
04-01-93	36	1000	24.8	7.47	7.88	40.8	68.4	188	0.00	0.00	0.000	0.00000
04-02-93	37	1000	24.9	7.41	7.92							
04-03-93	38	1100	24.9	7.46	8.08							
04-04-93	39	1300	24.8	7.41	8.18							
04-05-93	40	900	24.8	7.44	8.31							
04-06-93	41	1100	24.4	7.48	8.23							

04-07-93	42	900	25.0	7.54	8.36	40.8	85.5	189	0.00	0.00	0.00000
04-08-93	43	900	25.3	7.51	8.20						
04-09-93	44	900	25.3	7.53	8.04						
04-10-93	45	1000	25.7	7.50	7.85						
04-11-93	46	800	24.8	7.51	8.33						
04-12-93	47	1000	25.2	7.47	8.07						
04-13-93	48	900	25.0	7.51	7.85						
04-14-93	49	600	25.1	7.51	7.52						
04-15-93	50	900	25.4	7.49	7.49						
04-16-93	51	1000	25.7	7.49	8.38	40.8	85.5	189	0.00	0.022	0.00039
04-17-93	52	1000	25.3	7.50	7.59						
04-18-93	53	1000	24.9	7.51	7.69						
04-19-93	54	900	25.1	7.52	7.76						
04-20-93	55	900	25.6	7.47	7.65						
04-21-93	56	1000	25.7	7.49	7.44						
04-22-93	57	900	25.0	7.53	7.44	40.8	85.5	187	0.00	0.000	0.00000
04-23-93	58	900	24.9	7.51	7.09						
04-24-93	59	1000	25.1	7.48	7.78						
04-25-93	60	800	25.4	7.48	7.88						
04-26-93	61	900	25.4	7.43	7.30						
04-27-93	62	1000	24.4	7.54	7.96						
04-28-93	63	900	25.1	7.35	7.43	40.8	85.5	192	0.00	0.027	0.00043
04-29-93	64	1000	25.0	7.46	7.68						
04-30-93	65	1000	25.3	7.42	7.59						
05-01-93	66	1000	25.5	7.39	8.13						
05-02-93	67	1000	25.6	7.40	7.87						
05-03-93	68	1000	25.6	7.41	8.03						
05-04-93	69	1000	25.8	7.44	7.47						
05-05-93	70	900	25.7	7.36	7.38	40.8	85.5	197	0.00	0.032	0.00040
05-06-93	71	1000	25.2	7.34	7.24						
05-07-93	72	900	24.9	7.37	7.24						
05-08-93	73	1640	25.2	7.20	5.28						
05-09-93	74	1440	25.1	7.26	5.24						
05-10-93	75	1000	24.8	7.35	6.94						
05-11-93	76	900	25.2	7.44	7.58						
05-12-93	77	1000	25.3	7.41	6.99						
05-13-93	78	1000	25.3	7.44	7.08	40.8	85.5	194	0.00	0.000	0.00000
05-14-93	79	800	25.0	7.51	7.15						
05-15-93	80	800	25.1	7.50	7.49						
05-16-93	81	1100	25.3	7.47	7.62						
05-17-93	82	900	25.1	7.36	7.56						
05-18-93	83	1000	25.1	7.37	7.66						
05-19-93	84	1000	25.0	7.49	7.36						
05-20-93	85	900	25.2	7.44	7.08	40.8	85.5	203	0.00	0.046	0.00074
05-21-93	86	900	25.0	7.40	7.20						
05-22-93	87	800	24.7	7.54	7.41						
05-23-93	88	1000	24.6	7.45	7.32						
05-24-93	89	800	24.8	7.45	7.25						
05-25-93	90	1000	24.9	7.51	6.96						
05-26-93	91	900	24.9	7.54	7.36						
05-27-93	92	900	24.9	7.44	7.16						
05-28-93	93	1000	25.0	7.49	7.32	40.8	85.5	190	0.00	0.058	0.00089
05-29-93	94	1200	25.1	7.42	7.50						
05-30-93	95	900	24.9	7.47	6.93						







09-16-93	204	930	25.2	7.40	6.67	40.8	85.5	203	0.00	0.00	0.00000
09-17-93	205	930	24.6	7.30	6.86						
09-18-93	206	800	24.7	7.44	6.99						
09-19-93	207	1300	24.5	7.39	7.24						
09-20-93	208	930	24.5	7.36	7.22						
09-21-93	209	930	26.0	7.45	6.50						
09-22-93	210	900	25.3	7.27	6.73						
09-23-93	211	930	25.2	7.35	6.97	40.8	85.5	208	0.00	0.00	0.00000
09-24-93	212	1000	25.3	7.39	6.76						
09-25-93	213	900	25.1	7.39	7.13						
09-26-93	214	2100	25.7	7.52	7.12						
09-27-93	215	1000	25.4	7.44	6.77						
09-28-93	216	900	24.8	7.40	7.12						
09-29-93	217	930	24.8	7.41	7.09	40.8	85.5	209	0.00	0.00	0.00011
09-30-93	218	1300	24.6	7.24	7.13						
10-01-93	219	1100	24.2	7.31	8.41						
10-02-93	220	830	24.7	7.35	7.16						
10-03-93	221	830	24.9	7.33	6.88						
10-04-93	222	1000	24.4	7.31	7.03						
10-05-93	223	1000	24.9	7.32	6.69						
10-06-93	224	930	24.5	7.42	7.26						
10-07-93	225	930	24.9	7.46	7.09	47.6	85.5	206	0.00	0.00	0.00000
10-08-93	226	1000	25.0	7.36	7.06						
10-09-93	227	1130	25.0	7.42	7.13						
10-10-93	228	1130	24.6	7.42	7.33						
10-11-93	229	1600	24.6	7.45	7.36						
10-12-93	230	1000	24.5	7.33	7.25						
10-13-93	231	930	24.7	7.39	7.11						
10-14-93	232	1000	24.7	7.36	7.11	47.6	85.5	205	0.00	0.00	0.00000
10-15-93	233	1000	24.8	7.25	7.06						
10-16-93	234	1230	24.7	7.27	7.08						
10-17-93	235	1030	24.8	7.37	6.97						
10-18-93	236	1000	24.8	7.30	6.92						
10-19-93	237	900	24.8	7.26	6.97						
10-20-93	238	1000	24.8	7.38	7.35						
10-21-93	239	1000	24.8	7.39	7.15	47.6	85.5	206	0.00	0.00	0.00000
10-22-93	240	800	24.6	7.28	6.99						
10-23-93	241	700	24.4	7.35	7.47						
10-24-93	242	800	24.4	7.23	7.11						
10-25-93	243	1000	24.4	7.28	6.74						
10-26-93	244	1000	24.6	7.29	7.22						
10-27-93	245	1000	24.4	7.34	7.24						
10-28-93	246	1000	24.9	7.43	7.16	47.6	85.5	199	0.00	0.00	0.00012
10-29-93	247	1230	24.7	7.34	7.20						
10-30-93	248	700	25.1	7.41	7.25						
10-31-93	249	800	24.7	7.49	7.17						
11-01-93	250	930	24.5	7.31	7.17						
11-02-93	251	930	24.9	7.35	7.01						
11-03-93	252	1000	25.1	7.32	6.80						
11-04-93	253	1000	25.0	7.24	6.82	47.6	85.5	206	0.00	0.00	0.00000
11-05-93	254	1000	25.2	7.33	6.77						
11-06-93	255	600	25.3	7.22	6.86						
11-07-93	256	1000	25.0	7.28	6.74						
11-08-93	257	1000	24.8	7.28	6.92						



TANK No. 5  
TANK CONCENTRATION: 1% GROUNDWATER (WELL CC-33B)  
NO DEN EXPOSURE

Date	Test Day	Time (Military)	Temperature (Celsius)	pH	Dissolved Oxygen (mg/L)	Alkalinity (mg/L as CaCO3)	Hardness (mg/L as CaCO3)	Conductivity (umohs/cm)	Total Residual Chlorine (mg/L)	Free Available Chlorine (mg/L)	Total Ammonia- Nitrogen (mg/L)	Total Unionized Ammonia- Nitrogen (mg/L)
02-25-93	1	1500	24.7	6.74	7.72							
02-26-93	2	1000	24.1	7.15	7.67							
02-27-93	3	1000	24.4	7.12	7.46							
02-28-93	4	1100	24.7	7.08	7.38	34.0	85.5					
03-01-93	5	930	24.7	7.07	7.23							
03-02-93	6	1000	25.4	7.03	7.06							
03-03-93	7	1000	25.9	7.28	7.79							
03-04-93	8	1000	25.2	7.35	7.77							
03-05-93	9	800	25.6	7.35	7.52							
03-06-93	10	1000	24.9	7.20	7.78	34.0	85.5	320				
03-07-93	11	1100	24.9	7.04	7.88							
03-08-93	12	900	25.0	7.00	7.74							
03-09-93	13	930	25.3	7.17	7.58							
03-10-93	14	900	24.9	7.02	7.69							
03-11-93	15	900	25.3	7.39	7.54	54.4	85.5	222	0.00	0.00		
03-12-93	16	800	24.5	7.29	8.00							
03-13-93	17	1600	24.8	7.05	7.82							
03-14-93	18	1500	24.9	7.14	7.77							
03-15-93	19	900	24.7	7.05	7.93							
03-16-93	20	900	25.3	7.16	7.90							
03-17-93	21	900	25.5	7.17	7.43	34.0	85.5	433	0.00	0.00	0.019	0.00016
03-18-93	22	1030	25.3	7.02	7.72							
03-19-93	23	1000	25.3	7.08	7.60							
03-20-93	24	1100	26.8	7.13	7.69							
03-21-93	25	1230	25.5	7.12	8.09							
03-22-93	26	900	25.0	7.18	8.03							
03-23-93	27	900	24.9	7.12	7.96							
03-24-93	28	900	25.3	7.04	7.80							
03-25-93	29	900	25.1	6.96	7.78							
03-26-93	30	800	24.9	7.14	8.02	34.0	68.4	216	0.00	0.00	0.000	0.00000
03-27-93	31	1000	25.3	7.16	7.78							
03-28-93	32	1000	25.6	7.27	7.70							
03-29-93	33	1100	25.8	7.32	7.76							
03-30-93	34	1100	25.5	7.17	7.62							
03-31-93	35	1000	25.6	7.33	6.23							
04-01-93	36	1000	24.9	7.45	8.09	40.8	85.5	204	0.00	0.00	0.000	0.00000
04-02-93	37	1000	24.9	7.40	8.21							
04-03-93	38	1100	24.8	7.46	8.37							
04-04-93	39	1300	24.8	7.44	8.54							
04-05-93	40	900	24.8	7.38	8.45							
04-06-93	41	1100	24.5	7.40	8.26							

04-07-93	42	900	25.1	7.48	8.29	40.8	85.5	207	0.00	0.00	0.0000
04-08-93	43	900	25.3	7.45	8.13						
04-09-93	44	900	25.4	7.47	7.98						
04-10-93	45	1000	25.7	7.40	7.73						
04-11-93	46	800	24.9	7.42	8.24						
04-12-93	47	1000	25.4	7.42	8.16						
04-13-93	48	900	25.1	7.44	7.89						
04-14-93	49	600	25.2	7.44	7.57						
04-15-93	50	900	25.5	7.44	7.60						
04-16-93	51	1000	25.7	7.48	8.65	40.8	85.5	205	0.00	0.017	0.00027
04-17-93	52	1000	25.5	7.47	7.75						
04-18-93	53	1000	24.9	7.54	7.87						
04-19-93	54	900	25.2	7.51	7.98						
04-20-93	55	900	25.6	7.43	7.82						
04-21-93	56	1000	25.6	7.44	7.63						
04-22-93	57	900	25.0	7.49	7.38	40.8	85.5	201	0.00	0.000	0.00000
04-23-93	58	900	24.9	7.46	7.38						
04-24-93	59	1000	25.2	7.43	8.11						
04-25-93	60	800	25.4	7.43	8.09						
04-26-93	61	900	25.4	7.41	7.43						
04-27-93	62	1000	24.4	7.55	8.13						
04-28-93	63	900	25.1	7.34	7.74						
04-29-93	64	1000	25.1	7.45	7.75	40.8	85.5	211	0.00	0.019	0.00030
04-30-93	65	1000	25.3	7.45	8.16						
05-01-93	66	1000	25.5	7.39	8.24						
05-02-93	67	1000	25.6	7.36	7.97						
05-03-93	68	1000	25.6	7.37	8.10						
05-04-93	69	1000	25.8	7.39	7.51						
05-05-93	70	900	25.7	7.39	7.39						
05-06-93	71	1000	25.2	7.35	7.42	40.8	85.5	215	0.00	0.019	0.00024
05-07-93	72	900	24.9	7.35	7.56						
05-08-93	73	1640	25.2	7.25	5.54						
05-09-93	74	1440	25.0	7.31	6.22						
05-10-93	75	1000	25.0	7.32	7.24						
05-11-93	76	900	25.2	7.39	7.81						
05-12-93	77	1000	25.3	7.34	7.06						
05-13-93	78	1000	25.2	7.37	7.22						
05-14-93	79	800	24.8	7.43	7.31	40.8	85.5	208	0.00	0.000	0.00000
05-15-93	80	800	25.0	7.40	7.65						
05-16-93	81	1100	25.2	7.39	7.83						
05-17-93	82	900	25.0	7.28	7.80						
05-18-93	83	1000	25.0	7.29	7.88						
05-19-93	84	1000	25.1	7.37	7.42						
05-20-93	85	900	25.3	7.31	7.18	40.8	85.5	215	0.00	0.046	0.00054
05-21-93	86	900	24.9	7.32	7.34						
05-22-93	87	800	24.6	7.44	7.47						
05-23-93	88	1000	24.5	7.37	7.48						
05-24-93	89	800	24.7	7.33	7.35						
05-25-93	90	1000	24.8	7.41	7.02						
05-26-93	91	900	24.9	7.43	7.27						
05-27-93	92	900	24.8	7.32	7.18						
05-28-93	93	1000	24.9	7.35	7.19	40.8	85.5	198	0.00	0.047	0.00055
05-29-93	94	1200	25.1	7.31	7.45						
05-30-93	95	900	24.8	7.38	6.91						



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09-16-93	204	930	25.2	7.30	6.50	40.8	85.5	223	0.00	0.00	0.00000
09-17-93	205	930	24.5	7.22	6.71						
09-18-93	206	800	24.7	7.34	6.90						
09-19-93	207	1300	24.5	7.31	7.21						
09-20-93	208	930	24.4	7.24	7.03						
09-21-93	209	930	26.0	7.36	6.34						
09-22-93	210	900	25.3	7.17	6.52						
09-23-93	211	930	25.1	7.27	6.91	40.8	85.5	231	0.00	0.00	0.00000
09-24-93	212	1000	25.3	7.28	6.70						
09-25-93	213	900	25.1	7.29	7.00						
09-26-93	214	2100	25.7	7.40	7.12						
09-27-93	215	1000	25.4	7.34	6.78						
09-28-93	216	900	24.8	7.32	7.05						
09-29-93	217	930	24.7	7.29	7.05	40.8	85.5	230	0.00	0.00	0.00008
09-30-93	218	1300	24.6	7.13	7.07						
10-01-93	219	1100	24.0	7.23	8.33						
10-02-93	220	830	24.7	7.24	6.96						
10-03-93	221	830	24.9	7.29	6.80						
10-04-93	222	1000	24.5	7.21	7.00						
10-05-93	223	1000	24.9	7.22	6.75						
10-06-93	224	930	24.4	7.33	7.19	47.6	85.5	226	0.00	0.00	0.00000
10-07-93	225	930	24.9	7.37	7.03						
10-08-93	226	1000	24.9	7.29	7.06						
10-09-93	227	1130	24.9	7.35	7.12						
10-10-93	228	1130	24.6	7.34	7.31						
10-11-93	229	1600	24.5	7.38	7.37						
10-12-93	230	1000	24.4	7.27	7.25						
10-13-93	231	930	24.7	7.32	7.18						
10-14-93	232	1000	24.6	7.30	7.15	40.8	85.5	225	0.00	0.00	0.00000
10-15-93	233	1000	24.7	7.22	7.14						
10-16-93	234	1230	24.6	7.22	7.14						
10-17-93	235	1030	24.7	7.29	7.09						
10-18-93	236	1000	24.7	7.25	7.02						
10-19-93	237	900	24.7	7.21	7.07						
10-20-93	238	1000	24.8	7.29	7.40						
10-21-93	239	1000	24.8	7.28	7.15	40.8	85.5	232	0.00	0.00	0.00000
10-22-93	240	800	24.6	7.25	6.95						
10-23-93	241	700	24.4	7.29	7.63						
10-24-93	242	800	24.4	7.19	7.24						
10-25-93	243	1000	24.4	7.19	6.68						
10-26-93	244	1000	24.6	7.22	7.26						
10-27-93	245	1000	24.4	7.27	7.26	40.8	85.5	220	0.00	0.00	0.00023
10-28-93	246	1000	25.0	7.34	7.00						
10-29-93	247	1230	24.7	7.28	7.11						
10-30-93	248	700	25.1	7.33	7.02						
10-31-93	249	800	24.7	7.43	7.07						
11-01-93	250	930	24.5	7.28	7.05						
11-02-93	251	930	24.8	7.29	7.03						
11-03-93	252	1000	24.9	7.22	6.91						
11-04-93	253	1000	24.9	7.20	6.89	40.8	85.5	227	0.00	0.00	0.00000
11-05-93	254	1000	25.2	7.27	6.83						
11-06-93	255	600	25.3	7.17	6.74						
11-07-93	256	1000	24.9	7.22	6.79						
11-08-93	257	1000	24.8	7.23	7.00						





TANK No. 6  
TANK CONCENTRATION: 1% GROUNDWATER (WELL CC-33B)  
NO DEN EXPOSURE

Date	Test Day	Time (Military)	Temperature (Celsius)	pH	Dissolved Oxygen (mg/L)	Alkalinity (mg/L as CaCO3)	Hardness (mg/L as CaCO3)	Conductivity (umohs/cm)	Total Residual Chlorine (mg/L)	Free Available Chlorine (mg/L)	Total Ammonia- Nitrogen (mg/L)	Total Un-ionized Ammonia- Nitrogen (mg/L)
02-25-93	1	1500	24.8	6.76	7.67							
02-26-93	2	1000	24.1	7.15	7.69							
02-27-93	3	1000	24.4	7.12	7.36							
02-28-93	4	1100	24.7	7.08	7.36	34.0	85.5					
03-01-93	5	930	24.7	7.07	7.26							
03-02-93	6	1000	25.4	7.03	7.14							
03-03-93	7	1000	25.9	7.29	7.78							
03-04-93	8	1000	25.2	7.36	7.79							
03-05-93	9	800	25.6	7.37	7.54							
03-06-93	10	1000	24.9	7.19	7.75							
03-07-93	11	1100	24.9	7.03	7.90							
03-08-93	12	900	25.0	7.00	7.78							
03-09-93	13	930	25.3	7.17	7.62							
03-10-93	14	900	24.8	7.02	7.77							
03-11-93	15	900	25.3	7.40	7.60	54.4	85.5	229	0.00	0.00		
03-12-93	16	800	24.5	7.29	8.08							
03-13-93	17	1600	24.8	7.04	7.83							
03-14-93	18	1500	24.9	7.14	7.80							
03-15-93	19	900	24.6	7.05	7.90							
03-16-93	20	900	25.3	7.16	7.90							
03-17-93	21	900	25.5	7.17	7.50	34.0	85.5	439	0.00	0.00	0.020	0.00017
03-18-93	22	1030	25.3	7.01	7.75							
03-19-93	23	1000	25.4	7.11	7.66							
03-20-93	24	1100	26.8	7.13	7.64							
03-21-93	25	1230	25.5	7.12	8.04							
03-22-93	26	900	25.0	7.18	7.99							
03-23-93	27	900	24.9	7.12	7.93							
03-24-93	28	900	25.3	7.04	7.80							
03-25-93	29	900	25.1	6.96	7.78	34.0	68.4	223	0.00	0.00	0.0000	0.00000
03-26-93	30	800	24.8	7.14	8.01							
03-27-93	31	1000	25.3	7.15	7.75							
03-28-93	32	1000	25.7	7.27	7.69							
03-29-93	33	1100	25.9	7.32	7.75							
03-30-93	34	1100	25.6	7.11	7.60							
03-31-93	35	1000	25.6	7.33	6.22							
04-01-93	36	1000	24.9	7.44	8.12	40.8	85.5	210	0.00	0.00	0.0000	0.00000
04-02-93	37	1000	24.9	7.39	8.22							
04-03-93	38	1100	24.9	7.45	8.44							
04-04-93	39	1300	24.8	7.42	8.58							
04-05-93	40	900	24.8	7.35	8.48							
04-06-93	41	1100	24.5	7.40	8.34							

04-07-93	42	900	25.0	7.47	8.40	40.8	85.5	211	0.00	0.00	0.00000
04-08-93	43	900	25.3	7.44	8.18						
04-09-93	44	900	25.4	7.46	8.01						
04-10-93	45	1000	25.7	7.39	7.77						
04-11-93	46	800	24.8	7.41	8.20						
04-12-93	47	1000	25.3	7.41	8.18						
04-13-93	48	900	25.0	7.43	7.92						
04-14-93	49	600	25.1	7.43	7.53						
04-15-93	50	900	25.4	7.43	7.65	40.8	85.5	209	0.00	0.009	0.00014
04-16-93	51	1000	25.7	7.47	8.69						
04-17-93	52	1000	25.4	7.46	7.83						
04-18-93	53	1000	24.8	7.54	7.90						
04-19-93	54	900	25.2	7.50	7.96						
04-20-93	55	900	25.6	7.43	7.80						
04-21-93	56	1000	25.7	7.42	7.62						
04-22-93	57	900	25.0	7.48	7.62	40.8	85.5	206	0.00	0.000	0.00000
04-23-93	58	900	24.9	7.44	7.35						
04-24-93	59	1000	25.2	7.42	8.09						
04-25-93	60	800	25.4	7.42	8.09						
04-26-93	61	900	25.4	7.41	7.43						
04-27-93	62	1000	24.4	7.54	8.14						
04-28-93	63	900	25.1	7.34	7.73						
04-29-93	64	1000	25.0	7.44	7.76	40.8	85.5	217	0.00	0.024	0.00037
04-30-93	65	1000	25.3	7.42	7.93						
05-01-93	66	1000	25.5	7.38	8.28						
05-02-93	67	1000	25.6	7.35	7.94						
05-03-93	68	1000	25.6	7.34	7.90						
05-04-93	69	1000	25.8	7.37	7.38						
05-05-93	70	900	25.7	7.35	7.23						
05-06-93	71	1000	25.2	7.32	7.25	40.8	85.5	222	0.00	0.026	0.00031
05-07-93	72	900	24.9	7.32	7.22						
05-08-93	73	1640	25.2	7.20	5.70						
05-09-93	74	1440	25.1	7.29	5.35						
05-10-93	75	1000	24.9	7.30	7.03						
05-11-93	76	900	25.2	7.36	7.61						
05-12-93	77	1000	25.3	7.34	7.00	40.8	85.5	216	0.00	0.000	0.00000
05-13-93	78	1000	25.2	7.34	7.10						
05-14-93	79	800	24.9	7.40	7.22						
05-15-93	80	800	25.0	7.39	7.55						
05-16-93	81	1100	25.2	7.37	7.71						
05-17-93	82	900	25.0	7.28	7.65						
05-18-93	83	1000	25.0	7.27	7.78						
05-19-93	84	1000	25.0	7.37	7.42						
05-20-93	85	900	25.2	7.31	7.20	40.8	85.5	220	0.00	0.051	0.00059
05-21-93	86	900	24.9	7.32	7.35						
05-22-93	87	800	24.6	7.43	7.50						
05-23-93	88	1000	24.5	7.36	7.44						
05-24-93	89	800	24.7	7.33	7.37						
05-25-93	90	1000	24.8	7.41	7.05						
05-26-93	91	900	24.9	7.41	7.29						
05-27-93	92	900	24.8	7.31	7.11						
05-28-93	93	1000	24.9	7.35	7.20	40.8	85.5	204	0.00	0.050	0.00057
05-29-93	94	1200	25.1	7.30	7.44						
05-30-93	95	900	24.8	7.34	6.80						





09-16-93	204	930	25.2	7.30	6.60	40.8	85.5	223	0.00	0.00	0.00000
09-17-93	205	930	24.5	7.22	6.82						
09-18-93	206	800	24.7	7.34	7.04						
09-19-93	207	1300	24.5	7.31	7.21						
09-20-93	208	930	24.4	7.24	7.20						
09-21-93	209	930	26.0	7.36	6.45						
09-22-93	210	900	25.3	7.17	6.75						
09-23-93	211	930	25.1	7.27	6.91	40.8	85.5	230	0.00	0.00	0.00000
09-24-93	212	1000	25.3	7.28	6.75						
09-25-93	213	900	25.1	7.29	7.04						
09-26-93	214	2100	25.7	7.40	7.21						
09-27-93	215	1000	25.4	7.34	6.90						
09-28-93	216	900	24.8	7.32	7.19						
09-29-93	217	930	24.7	7.29	7.05	40.8	85.5	228	0.00	0.00	0.00010
09-30-93	218	1300	24.5	7.17	7.13						
10-01-93	219	1100	24.1	7.22	8.32						
10-02-93	220	830	24.7	7.27	6.84						
10-03-93	221	830	24.9	7.27	6.82						
10-04-93	222	1000	24.4	7.21	7.01						
10-05-93	223	1000	24.8	7.22	6.84						
10-06-93	224	930	24.4	7.33	7.21						
10-07-93	225	930	24.8	7.37	7.07	47.6	85.5	226	0.00	0.00	0.00000
10-08-93	226	1000	24.9	7.29	7.10						
10-09-93	227	1130	24.9	7.35	7.18						
10-10-93	228	1130	24.6	7.35	7.43						
10-11-93	229	1600	24.5	7.39	7.52						
10-12-93	230	1000	24.4	7.28	7.34						
10-13-93	231	930	24.7	7.33	7.26						
10-14-93	232	1000	24.6	7.30	7.22	40.8	85.5	225	0.00	0.00	0.00000
10-15-93	233	1000	24.7	7.22	7.21						
10-16-93	234	1230	24.6	7.23	7.19						
10-17-93	235	1030	24.7	7.29	7.12						
10-18-93	236	1000	24.7	7.25	7.08						
10-19-93	237	900	24.7	7.21	7.22						
10-20-93	238	1000	24.8	7.31	7.40						
10-21-93	239	1000	24.8	7.31	7.23	40.8	85.5	221	0.00	0.00	0.00000
10-22-93	240	800	24.6	7.28	6.97						
10-23-93	241	700	24.3	7.30	7.50						
10-24-93	242	800	24.3	7.20	7.23						
10-25-93	243	1000	24.4	7.19	6.69						
10-26-93	244	1000	24.6	7.22	7.27						
10-27-93	245	1000	24.4	7.27	7.30						
10-28-93	246	1000	24.9	7.34	7.11	40.8	85.5	220	0.00	0.00	0.00022
10-29-93	247	1230	24.6	7.28	7.19						
10-30-93	248	700	25.1	7.33	7.18						
10-31-93	249	800	24.7	7.43	7.12						
11-01-93	250	930	24.4	7.28	7.12						
11-02-93	251	930	24.8	7.29	7.10						
11-03-93	252	1000	24.9	7.21	6.92						
11-04-93	253	1000	24.9	7.20	6.95	40.8	85.5	228	0.00	0.00	0.00000
11-05-93	254	1000	25.1	7.27	6.91						
11-06-93	255	600	25.3	7.17	6.88						
11-07-93	256	1000	24.9	7.22	6.79						
11-08-93	257	1000	24.8	7.23	6.98						



TANK No. 7  
TANK CONCENTRATION: 1% GROUNDWATER (WELL CC-33B)  
DEN EXPOSURE: 10 mg/L

Date	Test Day	Time (Military)	Temperature (Celsius)	pH	Dissolved Oxygen (mg/L)	Alkalinity (mg/L as CaCO3)	Hardness (mg/L as CaCO3)	Conductivity (umohs/cm)	Total Residual Chlorine (mg/L)	Free Available Chlorine (mg/L)	Total Ammonia- Nitrogen (mg/L)	Total Un-ionized Ammonia- Nitrogen (mg/L)
02-25-93	1	1500	24.7	6.76	7.67							
02-26-93	2	1000	24.1	7.15	7.66							
02-27-93	3	1000	24.4	7.14	7.40							
02-28-93	4	1100	24.7	7.09	7.38	34.0	85.5					
03-01-93	5	930	24.8	7.08	7.31							
03-02-93	6	1000	25.4	7.05	7.08							
03-03-93	7	1000	25.9	7.30	7.80							
03-04-93	8	1000	25.2	7.38	7.76							
03-05-93	9	800	25.6	7.36	7.52							
03-06-93	10	1000	24.9	7.20	7.79	34.0	85.5	316				
03-07-93	11	1100	24.9	7.02	7.87							
03-08-93	12	900	25.0	7.00	7.78							
03-09-93	13	930	25.3	7.18	7.58							
03-10-93	14	900	24.9	7.03	7.79							
03-11-93	15	900	25.3	7.40	7.56							
03-12-93	16	800	24.5	7.29	8.07							
03-13-93	17	1600	24.8	7.05	7.77							
03-14-93	18	1500	24.9	7.14	7.77							
03-15-93	19	900	24.7	7.05	7.93							
03-16-93	20	900	25.3	7.16	7.88							
03-17-93	21	900	25.5	7.17	7.50							
03-18-93	22	1030	25.3	7.01	7.56	34.0	85.5	425	0.00	0.00	0.023	0.00020
03-19-93	23	1000	25.4	7.11	7.06							
03-20-93	24	1100	27.0	7.14	7.58							
03-21-93	25	1230	25.5	7.12	8.00							
03-22-93	26	900	25.0	7.18	7.95							
03-23-93	27	900	25.0	7.12	7.89							
03-24-93	28	900	25.3	7.04	7.79							
03-25-93	29	900	25.1	6.96	7.75	34.0	68.4	216	0.00	0.00	0.000	0.00000
03-26-93	30	800	24.8	7.14	8.00							
03-27-93	31	1000	25.3	7.15	7.72							
03-28-93	32	1000	25.7	7.27	7.62							
03-29-93	33	1100	25.9	7.32	7.60							
03-30-93	34	1100	25.6	7.12	7.68							
03-31-93	35	1000	25.6	7.29	6.07							
04-01-93	36	1000	25.0	7.41	7.95	40.8	68.4	206	0.00	0.00	0.000	0.00000
04-02-93	37	1000	24.9	7.35	8.06							
04-03-93	38	1100	24.9	7.40	8.20							
04-04-93	39	1300	24.8	7.38	8.34							
04-05-93	40	900	24.8	7.33	8.40							
04-06-93	41	1100	24.5	7.37	8.27							



04-07-93	42	900	25.1	7.44	8.31	40.8	85.5	206	0.00	0.00	0.00000
04-08-93	43	900	25.3	7.43	8.16						
04-09-93	44	900	25.5	7.45	8.00						
04-10-93	45	1000	25.8	7.38	7.69						
04-11-93	46	800	24.9	7.41	8.20						
04-12-93	47	1000	25.4	7.41	8.00						
04-13-93	48	900	25.2	7.43	7.85						
04-14-93	49	600	25.2	7.43	7.53						
04-15-93	50	900	25.5	7.43	7.53						
04-16-93	51	1000	25.7	7.45	8.49						
04-17-93	52	1000	25.5	7.45	7.60						
04-18-93	53	1000	25.0	7.54	7.77						
04-19-93	54	900	25.3	7.50	7.83						
04-20-93	55	900	25.7	7.44	7.95						
04-21-93	56	1000	25.7	7.44	7.59						
04-22-93	57	900	25.1	7.49							
04-23-93	58	900	25.0	7.46	7.37						
04-24-93	59	1000	25.3	7.42	7.97						
04-25-93	60	800	25.5	7.43	7.98						
04-26-93	61	900	25.5	7.41	7.43						
04-27-93	62	1000	24.5	7.55	8.06						
04-28-93	63	900	25.2	7.35	7.63						
04-29-93	64	1000	25.2	7.44	7.72						
04-30-93	65	1000	25.4	7.43	7.94						
05-01-93	66	1000	25.6	7.34	8.18						
05-02-93	67	1000	25.7	7.33	7.90						
05-03-93	68	1000	25.7	7.33	7.91						
05-04-93	69	1000	25.9	7.37	7.37						
05-05-93	70	900	25.8	7.31	7.09						
05-06-93	71	1000	25.3	7.30	7.15						
05-07-93	72	900	25.0	7.29	7.27						
05-08-93	73	1640	25.4	7.19	5.28						
05-09-93	74	1440	25.2	7.29	5.14						
05-10-93	75	1000	25.1	7.30	7.05						
05-11-93	76	900	25.2	7.36	7.56						
05-12-93	77	1000	25.3	7.34	6.96						
05-13-93	78	1000	25.3	7.36	7.14						
05-14-93	79	800	24.9	7.41	7.10						
05-15-93	80	800	25.1	7.40	7.51						
05-16-93	81	1100	25.3	7.38	7.61						
05-17-93	82	900	25.1	7.28	7.56						
05-18-93	83	1000	25.1	7.27	7.58						
05-19-93	84	1000	25.1	7.37	7.26						
05-20-93	85	900	25.3	7.32	6.98						
05-21-93	86	900	25.0	7.32	7.14						
05-22-93	87	800	24.7	7.44	7.25						
05-23-93	88	1000	24.6	7.36	7.15						
05-24-93	89	800	24.8	7.33	7.11						
05-25-93	90	1000	24.9	7.42	6.74						
05-26-93	91	900	24.9	7.44	7.18						
05-27-93	92	900	24.8	7.33	7.04						
05-28-93	93	1000	25.0	7.35	7.02						
05-29-93	94	1200	25.2	7.30	7.18						
05-30-93	95	900	24.9	7.35	6.76						



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09-16-93	204	930	25.3	7.30	6.66	40.8	85.5	222	0.00	0.00	0.0000
09-17-93	205	930	24.6	7.22	6.81						
09-18-93	206	800	24.7	7.34	7.00						
09-19-93	207	1300	24.5	7.31	7.24						
09-20-93	208	930	24.4	7.24	7.26						
09-21-93	209	930	26.1	7.36	6.48						
09-22-93	210	900	25.3	7.17	6.73						
09-23-93	211	930	25.1	7.27	7.00	40.8	85.5	228	0.00	0.00	0.00000
09-24-93	212	1000	25.3	7.28	6.76						
09-25-93	213	900	25.1	7.29	7.16						
09-26-93	214	2100	25.7	7.40	7.15						
09-27-93	215	1000	25.4	7.34	6.88						
09-28-93	216	900	24.8	7.32	7.20						
09-29-93	217	930	24.8	7.29	7.11	40.8	85.5	227	0.00	0.00	0.00009
09-30-93	218	1300	24.5	7.17	7.14						
10-01-93	219	1100	24.0	7.24	8.21						
10-02-93	220	830	24.7	7.27	6.96						
10-03-93	221	830	25.0	7.26	6.78						
10-04-93	222	1000	24.4	7.21	7.08						
10-05-93	223	1000	24.8	7.22	6.89						
10-06-93	224	930	24.4	7.33	7.33						
10-07-93	225	930	24.9	7.37	7.21	47.6	85.5	225	0.00	0.00	0.00000
10-08-93	226	1000	24.9	7.29	7.11						
10-09-93	227	1130	24.9	7.35	7.22						
10-10-93	228	1130	24.6	7.34	7.42						
10-11-93	229	1600	24.5	7.36	7.46						
10-12-93	230	1000	24.4	7.27	7.30						
10-13-93	231	930	24.7	7.32	7.25						
10-14-93	232	1000	24.6	7.30	7.23	40.8	85.5	224	0.00	0.00	0.00000
10-15-93	233	1000	24.7	7.18	7.18						
10-16-93	234	1230	24.6	7.22	7.22						
10-17-93	235	1030	24.7	7.29	7.17						
10-18-93	236	1000	24.7	7.25	7.08						
10-19-93	237	900	24.7	7.21	7.24						
10-20-93	238	1000	24.7	7.29	7.38						
10-21-93	239	1000	24.8	7.31	7.16	40.8	85.5	224	0.00	0.00	0.00003
10-22-93	240	800	24.6	7.28	6.93						
10-23-93	241	700	24.3	7.35	7.54						
10-24-93	242	800	24.3	7.21	7.17						
10-25-93	243	1000	24.3	7.19	6.78						
10-26-93	244	1000	24.6	7.22	7.24						
10-27-93	245	1000	24.3	7.27	7.19						
10-28-93	246	1000	24.9	7.33	7.07	40.8	85.5	218	0.00	0.00	0.00024
10-29-93	247	1230	24.7	7.27	7.11						
10-30-93	248	700	25.1	7.33	7.11						
10-31-93	249	800	24.7	7.43	7.02						
11-01-93	250	930	24.4	7.27	7.05						
11-02-93	251	930	24.8	7.29	7.09						
11-03-93	252	1000	24.9	7.22	6.94						
11-04-93	253	1000	24.9	7.20	6.96	40.8	85.5	225	0.00	0.00	0.00000
11-05-93	254	1000	25.2	7.28	6.99						
11-06-93	255	600	25.3	7.18	6.92						
11-07-93	256	1000	24.9	7.22	6.81						
11-08-93	257	1000	24.7	7.23	6.99						



TANK No. 8  
TANK CONCENTRATION: 1% GROUNDWATER (WELL CC-33B)  
DEN EXPOSURE: 10 mg/L

Date	Test Day	Time (Military)	Temperature (Celsius)	pH	Dissolved Oxygen (mg/L)	Alkalinity (mg/L as CaCO3)	Hardness (mg/L as CaCO3)	Conductivity (umohs/cm)	Total Residual Chlorine (mg/L)	Free Available Chlorine (mg/L)	Total Ammonia- Nitrogen (mg/L)	Total Unionized Ammonia- Nitrogen (mg/L)
02-25-93	1	1500	24.7	6.78	7.48							
02-26-93	2	1000	24.2	7.15	7.59							
02-27-93	3	1000	24.5	7.13	7.41							
02-28-93	4	1100	24.8	7.09	7.36	34.0	85.5					
03-01-93	5	930	24.8	7.08	7.31							
03-02-93	6	1000	25.5	7.05	6.94							
03-03-93	7	1000	26.0	7.30	7.79							
03-04-93	8	1000	25.3	7.38	7.77							
03-05-93	9	800	25.6	7.37	7.47							
03-06-93	10	1000	25.0	7.21	7.79	34.0	85.5	314				
03-07-93	11	1100	24.9	7.03	7.86							
03-08-93	12	900	25.0	7.01	7.77							
03-09-93	13	930	25.3	7.17	7.57							
03-10-93	14	900	24.8	7.03	7.75							
03-11-93	15	900	25.3	7.41	7.58				0.00			
03-12-93	16	800	24.5	7.31	8.04	54.4	85.5	215				
03-13-93	17	1600	24.9	7.05	7.77							
03-14-93	18	1500	24.9	7.14	7.75							
03-15-93	19	900	24.8	7.06	7.92							
03-16-93	20	900	25.3	7.16	7.87							
03-17-93	21	900	25.6	7.17	7.46	34.0	85.5	425	0.00	0.00	0.019	0.00017
03-18-93	22	1030	25.4	7.02	7.61							
03-19-93	23	1000	25.3	7.11	7.54							
03-20-93	24	1100	27.0	7.13	7.61							
03-21-93	25	1230	25.5	7.12	7.98							
03-22-93	26	900	25.1	7.18	7.96							
03-23-93	27	900	24.9	7.12	7.92							
03-24-93	28	900	25.3	7.04	7.78							
03-25-93	29	900	25.2	6.97	7.74	34.0	68.4	213	0.00	0.00	0.000	0.00000
03-26-93	30	800	24.8	7.14	8.00							
03-27-93	31	1000	25.3	7.15	7.69							
03-28-93	32	1000	25.7	7.27	7.61							
03-29-93	33	1100	25.9	7.32	7.60							
03-30-93	34	1100	25.6	7.17	7.50							
03-31-93	35	1000	25.6	7.29	6.08							
04-01-93	36	1000	25.0	7.43	8.00	40.8	68.4	206	0.00	0.00	0.000	0.00000
04-02-93	37	1000	24.9	7.37	8.10							
04-03-93	38	1100	24.9	7.41	8.20							
04-04-93	39	1300	24.8	7.40	8.27							
04-05-93	40	900	24.8	7.34	8.38							
04-06-93	41	1100	24.4	7.38	8.27							

04-07-93	42	900	25.0	7.45	8.31	40.8	85.5	208	0.00	0.00	0.00000
04-08-93	43	900	25.3	7.45	8.13						
04-09-93	44	900	25.4	7.47	8.03						
04-10-93	45	1000	25.8	7.39	7.70						
04-11-93	46	800	24.9	7.44	8.30						
04-12-93	47	1000	25.3	7.42	8.14						
04-13-93	48	900	25.1	7.45	7.90						
04-14-93	49	600	25.1	7.45	7.62						
04-15-93	50	900	25.5	7.45	7.62	40.8	85.5	204	0.00	0.009	0.00015
04-16-93	51	1000	25.7	7.47	8.60						
04-17-93	52	1000	25.4	7.46	7.67						
04-18-93	53	1000	24.9	7.54	7.79						
04-19-93	54	900	25.2	7.51	7.85						
04-20-93	55	900	25.7	7.45	7.93						
04-21-93	56	1000	25.8	7.46	7.60						
04-22-93	57	900	25.0	7.50	7.30	40.8	85.5	201	0.00	0.000	0.00000
04-23-93	58	900	25.0	7.47	7.93						
04-24-93	59	1000	25.3	7.43	7.93						
04-25-93	60	800	25.5	7.43	8.01						
04-26-93	61	900	25.5	7.41	7.36						
04-27-93	62	1000	24.5	7.55	7.98						
04-28-93	63	900	25.2	7.35	7.54						
04-29-93	64	1000	25.1	7.44	7.58	40.8	85.5	210	0.00	0.032	0.00050
04-30-93	65	1000	25.4	7.43	7.90						
05-01-93	66	1000	25.6	7.36	8.18						
05-02-93	67	1000	25.7	7.36	7.95						
05-03-93	68	1000	25.7	7.34	7.96						
05-04-93	69	1000	25.9	7.38	7.31						
05-05-93	70	900	25.8	7.33	7.08						
05-06-93	71	1000	25.4	7.32	7.13	40.8	85.5	216	0.00	0.031	0.00038
05-07-93	72	900	25.0	7.28	6.57						
05-08-93	73	1640	25.4	7.16	4.92						
05-09-93	74	1440	25.3	7.26	5.36						
05-10-93	75	1000	25.0	7.30	6.73						
05-11-93	76	900	25.2	7.36	7.41						
05-12-93	77	1000	25.3	7.34	7.03						
05-13-93	78	1000	25.3	7.37	7.14	40.8	85.5	211	0.00	0.000	0.00000
05-14-93	79	800	24.9	7.42	7.14						
05-15-93	80	800	25.1	7.41	7.48						
05-16-93	81	1100	25.3	7.39	7.67						
05-17-93	82	900	25.1	7.28	7.56						
05-18-93	83	1000	25.1	7.29	7.69						
05-19-93	84	1000	25.0	7.38	7.36						
05-20-93	85	900	25.2	7.33	7.08	40.8	85.5	218	0.00	0.051	0.00062
05-21-93	86	900	25.0	7.32	7.17						
05-22-93	87	800	24.6	7.44	7.34						
05-23-93	88	1000	24.6	7.37	7.21						
05-24-93	89	800	24.8	7.33	7.13						
05-25-93	90	1000	24.9	7.43	6.74						
05-26-93	91	900	24.9	7.44	7.37						
05-27-93	92	900	24.8	7.35	7.16						
05-28-93	93	1000	25.0	7.35	7.22	40.8	85.5	200	0.00	0.055	0.00068
05-29-93	94	1200	25.2	7.31	7.44						
05-30-93	95	900	24.9	7.34	6.83						





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09-16-93	204	930	25.3	7.30	6.69	40.8	85.5	222	0.00	0.00	0.00000
09-17-93	205	930	24.5	7.22	6.92						
09-18-93	206	800	24.7	7.34	7.04						
09-19-93	207	1300	24.5	7.31	7.34						
09-20-93	208	930	24.4	7.24	7.30						
09-21-93	209	930	26.1	7.36	6.57						
09-22-93	210	900	25.3	7.17	6.80						
09-23-93	211	930	25.1	7.27	7.05	40.8	85.5	229	0.00	0.00	0.00000
09-24-93	212	1000	25.3	7.28	6.95						
09-25-93	213	900	25.1	7.29	7.23						
09-26-93	214	2100	25.7	7.40	7.18						
09-27-93	215	1000	25.4	7.34	6.98						
09-28-93	216	900	24.8	7.32	7.26						
09-29-93	217	930	24.7	7.29	7.27	40.8	85.5	228	0.00	0.00	0.00005
09-30-93	218	1300	24.5	7.16	7.21						
10-01-93	219	1100	24.1	7.25	8.50						
10-02-93	220	830	24.7	7.29	6.92						
10-03-93	221	830	25.0	7.28	6.74						
10-04-93	222	1000	24.4	7.21	7.22						
10-05-93	223	1000	24.8	7.22	7.13						
10-06-93	224	930	24.3	7.33	7.50						
10-07-93	225	930	24.8	7.37	7.24	47.6	85.5	226	0.00	0.00	0.00000
10-08-93	226	1000	24.9	7.29	7.19						
10-09-93	227	1130	24.9	7.35	7.36						
10-10-93	228	1130	24.6	7.34	7.43						
10-11-93	229	1600	24.5	7.36	7.46						
10-12-93	230	1000	24.4	7.28	7.45						
10-13-93	231	930	24.7	7.32	7.36						
10-14-93	232	1000	24.5	7.30	7.37	40.8	85.5	224	0.00	0.00	0.00000
10-15-93	233	1000	24.7	7.18	7.28						
10-16-93	234	1230	24.6	7.22	7.28						
10-17-93	235	1030	24.7	7.29	7.23						
10-18-93	236	1000	24.7	7.25	7.18						
10-19-93	237	900	24.7	7.21	7.29						
10-20-93	238	1000	24.7	7.29	7.49						
10-21-93	239	1000	24.8	7.30	7.27	40.8	85.5	225	0.00	0.00	0.00000
10-22-93	240	800	24.6	7.28	6.87						
10-23-93	241	700	24.3	7.33	7.50						
10-24-93	242	800	24.3	7.20	7.21						
10-25-93	243	1000	24.4	7.19	6.73						
10-26-93	244	1000	24.6	7.21	7.15						
10-27-93	245	1000	24.4	7.27	7.21						
10-28-93	246	1000	24.9	7.33	7.10	40.8	85.5	218	0.00	0.00	0.00034
10-29-93	247	1230	24.7	7.27	7.06						
10-30-93	248	700	25.0	7.33	7.21						
10-31-93	249	800	24.7	7.42	7.14						
11-01-93	250	930	24.4	7.27	7.08						
11-02-93	251	930	24.8	7.29	7.05						
11-03-93	252	1000	24.9	7.21	6.90						
11-04-93	253	1000	24.9	7.20	6.97	40.8	85.5	225	0.00	0.00	0.00000
11-05-93	254	1000	25.2	7.28	6.92						
11-06-93	255	1000	25.3	7.18	6.90						
11-07-93	256	1000	24.9	7.22	6.76						
11-08-93	257	1000	24.7	7.23	7.01						



TANK No. 9  
TANK CONCENTRATION: 10% GROUNDWATER (WELL CC-33B)  
NO DEN EXPOSURE

Date	Test Day	Time (Military)	Temperature (Celsius)	pH	Dissolved Oxygen (mg/L)	Alkalinity (mg/L as CaCO3)	Hardness (mg/L as CaCO3)	Conductivity (umohs/cm)	Total Residual Chlorine (mg/L)	Free Available Chlorine (mg/L)	Total Ammonia- Nitrogen (mg/L)	Total Unionized Ammonia- Nitrogen (mg/L)
02-25-93	1	1500	24.6	6.53	7.57							
02-26-93	2	1000	24.0	6.70	7.62							
02-27-93	3	1000	24.4	6.88	7.44							
02-28-93	4	1100	24.8	6.95	7.36	34.0	102.6					
03-01-93	5	930	24.8	6.66	7.27							
03-02-93	6	1000	25.5	6.66	7.00							
03-03-93	7	1000	25.9	6.70	7.60							
03-04-93	8	1000	25.1	6.70	7.61							
03-05-93	9	800	25.4	6.70	7.36							
03-06-93	10	1000	24.9	6.52	7.63	34.0	102.6	459				
03-07-93	11	1100	24.9	6.31	7.74							
03-08-93	12	900	25.0	6.40	7.64							
03-09-93	13	930	25.2	6.57	7.40							
03-10-93	14	900	24.8	6.49	7.72							
03-11-93	15	900	25.3	6.88	7.41	47.6	102.6	369	0.00	0.00		
03-12-93	16	800	24.5	6.75	7.88							
03-13-93	17	1600	24.8	6.67	7.57							
03-14-93	18	1500	24.9	6.73	7.61							
03-15-93	19	900	24.7	6.74	7.72							
03-16-93	20	900	25.3	6.78	7.69							
03-17-93	21	900	25.5	6.73	7.29	34.0	102.6	568	0.00	0.00	0.030	0.00009
03-18-93	22	1030	25.4	6.78	7.45							
03-19-93	23	1000	25.8	7.10	7.47							
03-20-93	24	1100	26.9	6.73	7.47							
03-21-93	25	1230	25.6	6.72	7.83							
03-22-93	26	900	25.1	6.73	7.76							
03-23-93	27	900	25.0	6.71	7.73							
03-24-93	28	900	25.4	6.65	7.55	27.2	85.5	371	0.00	0.00	0.000	0.00000
03-25-93	29	900	25.1	6.65	7.63							
03-26-93	30	800	24.9	6.26	7.81							
03-27-93	31	1000	25.3	6.27	7.54							
03-28-93	32	1000	25.6	6.40	7.53							
03-29-93	33	1100	25.8	6.45	7.42							
03-30-93	34	1100	25.5	6.38	7.48							
03-31-93	35	1000	25.5	6.48	5.85	34.0	85.5	359	0.00	0.00	0.000	0.00000
04-01-93	36	1000	24.8	6.53	7.70							
04-02-93	37	1000	24.8	6.53	7.86							
04-03-93	38	1100	24.8	6.53	7.98							
04-04-93	39	1300	24.8	6.48	8.12							
04-05-93	40	900	24.8	6.47	8.23							
04-06-93	41	1100	24.7	6.49	8.01							

04-07-93	42	900	25.0	6.58	8.11	34.0	85.5	361	0.00	0.00	0.00000
04-08-93	43	900	25.2	6.58	7.93						
04-09-93	44	900	25.2	6.60	7.85						
04-10-93	45	1000	25.4	6.54	7.58						
04-11-93	46	800	24.8	6.58	8.07						
04-12-93	47	1000	25.2	6.61	7.93						
04-13-93	48	900	25.0	6.58	7.69						
04-14-93	49	600	25.0	6.61	7.51						
04-15-93	50	900	25.3	6.61	7.52						
04-16-93	51	1000	25.5	6.60	8.43						
04-17-93	52	1000	25.3	6.59	7.55						
04-18-93	53	1000	24.8	6.67	7.64						
04-19-93	54	900	25.1	6.60	7.72						
04-20-93	55	900	25.4	6.61	7.82						
04-21-93	56	1000	25.4	6.64	7.54						
04-22-93	57	900	24.8	6.64		34.0	102.6	344	0.00	0.00	0.00000
04-23-93	58	900	24.8	6.66	7.00						
04-24-93	59	1000	25.1	6.62	7.80						
04-25-93	60	800	25.2	6.60	7.86						
04-26-93	61	900	25.3	6.62	7.13						
04-27-93	62	1000	24.4	6.71	7.83						
04-28-93	63	900	25.0	6.64	7.46						
04-29-93	64	1000	25.0	6.66	7.27	34.0	102.6	348	0.00	0.00	0.00005
04-30-93	65	1000	25.2	6.67	7.81						
05-01-93	66	1000	25.4	6.65	8.10						
05-02-93	67	1000	25.4	6.65	7.81						
05-03-93	68	1000	25.4	6.65	7.90						
05-04-93	69	1000	25.5	6.69	7.21						
05-05-93	70	900	25.5	6.68	7.16						
05-06-93	71	1000	25.1	6.66	7.13	34.0	85.5	358	0.00	0.00	0.00006
05-07-93	72	900	24.9	6.71	7.22						
05-08-93	73	1640	25.2	6.63	4.96						
05-09-93	74	1440	25.2	6.78	5.71						
05-10-93	75	1000	24.9	6.63	6.92						
05-11-93	76	900	25.0	6.65	7.42						
05-12-93	77	1000	25.1	6.69	6.90						
05-13-93	78	1000	25.1	6.70	6.91	34.0	102.6	350	0.00	0.00	0.00000
05-14-93	79	800	24.8	6.74	6.87						
05-15-93	80	800	24.9	6.74	7.31						
05-16-93	81	1100	25.1	6.72	7.52						
05-17-93	82	900	24.9	6.64	7.40						
05-18-93	83	1000	24.9	6.66	7.47						
05-19-93	84	1000	25.2	6.76	7.15						
05-20-93	85	900	25.3	6.73	6.82	34.0	102.6	357	0.00	0.00	0.00019
05-21-93	86	900	24.9	6.71	6.94						
05-22-93	87	800	24.7	6.83	7.22						
05-23-93	88	1000	24.6	6.77	7.06						
05-24-93	89	800	24.7	6.70	7.01						
05-25-93	90	1000	24.9	6.85	6.59						
05-26-93	91	900	24.9	6.76	7.06						
05-27-93	92	900	24.8	6.62	7.07						
05-28-93	93	1000	24.9	6.65	6.91	34.0	102.6	361	0.00	0.00	0.00014
05-29-93	94	1200	25.1	6.64	7.18						
05-30-93	95	900	24.9	6.75	6.63						





09-16-93	204	930	25.2	6.70	6.32	34.0	102.6	382	0.00	0.00	0.0000
09-17-93	205	930	24.6	6.66	6.48						
09-18-93	206	800	24.8	6.77	6.78						
09-19-93	207	1300	24.6	6.72	7.07						
09-20-93	208	930	24.5	6.68	6.95						
09-21-93	209	930	25.9	6.80	6.20						
09-22-93	210	900	25.2	6.61	6.40						
09-23-93	211	930	25.1	6.69	6.73	34.0	102.6	406	0.00	0.00	0.00000
09-24-93	212	1000	25.2	6.70	6.51						
09-25-93	213	900	25.1	6.72	6.88						
09-26-93	214	2100	25.6	6.78	6.87						
09-27-93	215	1000	25.3	6.77	6.70						
09-28-93	216	900	24.8	6.75	7.02						
09-29-93	217	930	24.8	6.72	6.89	34.0	102.6	402	0.00	0.00	0.00001
09-30-93	218	1300	24.6	6.58	6.83						
10-01-93	219	1100	24.1	6.67	8.12						
10-02-93	220	830	24.8	6.73	6.87						
10-03-93	221	830	25.0	6.78	6.70						
10-04-93	222	1000	24.6	6.69	6.96						
10-05-93	223	1000	24.9	6.65	6.72						
10-06-93	224	930	24.5	6.77	7.08						
10-07-93	225	930	24.9	6.82	6.92	40.8	102.6	406	0.00	0.00	0.00000
10-08-93	226	1000	25.0	6.77	6.92						
10-09-93	227	1130	24.9	6.77	6.96						
10-10-93	228	1130	24.6	6.76	7.17						
10-11-93	229	1600	24.7	6.77	7.17						
10-12-93	230	1000	24.5	6.73	7.15						
10-13-93	231	930	24.8	6.74	6.97						
10-14-93	232	1000	24.7	6.74	6.95	34.0	102.6	399	0.00	0.00	0.00000
10-15-93	233	1000	24.8	6.65	6.90						
10-16-93	234	1230	24.7	6.66	6.81						
10-17-93	235	1030	24.8	6.73	6.86						
10-18-93	236	1000	24.7	6.69	6.86						
10-19-93	237	900	24.7	6.65	6.93						
10-20-93	238	1000	24.8	6.75	7.14						
10-21-93	239	1000	24.8	6.76	6.90	34.0	102.6	397	0.00	0.00	0.00001
10-22-93	240	800	24.7	6.85	6.88						
10-23-93	241	700	24.4	6.84	7.43						
10-24-93	242	800	24.4	6.83	7.11						
10-25-93	243	1000	24.5	6.64	6.57						
10-26-93	244	1000	24.7	6.67	7.06						
10-27-93	245	1000	24.4	6.76	7.07						
10-28-93	246	1000	24.9	6.77	6.74	34.0	102.6	380	0.00	0.00	
10-29-93	247	1230	24.7	6.78	6.70						
10-30-93	248	700	25.0	6.82	6.88						
10-31-93	249	800	24.7	6.87	6.83						
11-01-93	250	930	24.4	6.76	6.78						
11-02-93	251	930	24.8	6.79	6.83						
11-03-93	252	1000	25.0	6.74	6.66						
11-04-93	253	1000	24.9	6.70	6.70	34.0	102.6	392	0.00	0.00	0.00000
11-05-93	254	1000	25.1	6.78	6.65						
11-06-93	255	600	25.2	6.70	6.69						
11-07-93	256	1000	25.0	6.74	6.59						
11-08-93	257	1000	24.8	6.76	6.77						



11-09-93	258	1000	24.7	6.74	6.76	34.0	102.6	380	0.00	0.005	0.00002
11-10-93	259	1000	24.7	6.70	6.71						
11-11-93	260	1100	24.7	6.74	6.63						
11-12-93	261	1000	24.9	6.72	6.47						
11-13-93	262	1230	25.0	6.75	6.51						
11-14-93	263	900	25.0	6.73	6.53						
11-15-93	264	1000	25.2	6.71	6.35						
11-16-93	265	1000	25.0	6.66	6.46						
11-17-93	266	1200	25.2	6.66	5.79						
11-18-93	267	1000	24.9	6.73	6.50						
11-19-93	268	1000	24.9	6.75	6.44						
11-20-93	269	830	25.0	6.72	6.37						
11-21-93	270	1300	24.7	6.71	6.57						
11-22-93	271	930	24.6	6.71	6.60						
11-23-93	272	1000	24.8	6.69	6.74						
11-24-93	273	1300	24.7	6.81	6.14						
11-25-93	274	900	24.7	6.77	6.71						
11-26-93	275	1200	24.6	6.70	6.76						
11-27-93	276	1100	24.8	6.74	6.64						
11-28-93	277	1100	25.3	6.72	6.29						
11-29-93	278	600	24.1	7.40	7.71						
MEAN											
MINIMUM			25.0	6.70	6.90	35.0	100.9	373	0.00	0.016	0.00004
MAXIMUM			24.0	6.26	4.96	27.2	85.5	329	0.00	0.000	0.00000
Std Dev			26.9	7.40	8.43	47.6	102.6	568	0.00	0.092	0.00019
N			0.32	0.119	0.566	3.58	5.13	40.1	0.000	0.0215	0.000056
			278	278	277	40	40	39	38	37	37

TANK No. 10  
TANK CONCENTRATION: 10% GROUNDWATER (WELL CC-33B)  
NO DEN EXPOSURE

Date	Test Day	Time (Military)	Temperature (Celsius)	pH	Dissolved Oxygen (mg/L)	Alkalinity (mg/L as CaCO <sub>3</sub> )	Hardness (mg/L as CaCO <sub>3</sub> )	Conductivity (umohs/cm)	Total Residual Chlorine (mg/L)	Free Available Chlorine (mg/L)	Total Ammonia- Nitrogen (mg/L)	Total Un-ionized Ammonia- Nitrogen (mg/L)
02-25-93	1	1500	24.6	6.49	7.57							
02-26-93	2	1000	24.0	6.70	7.57							
02-27-93	3	1000	24.4	6.88	7.37							
02-28-93	4	1100	24.9	6.95	7.23	34.0	102.6					
03-01-93	5	930	24.8	6.65	7.17							
03-02-93	6	1000	25.5	6.66	6.97							
03-03-93	7	1000	25.9	6.69	7.64							
03-04-93	8	1000	25.1	6.70	7.64							
03-05-93	9	800	25.4	6.70	7.40							
03-06-93	10	1000	24.9	6.52	7.67	27.2	102.6	459				
03-07-93	11	1100	24.9	6.30	7.76							
03-08-93	12	900	25.0	6.39	7.66							
03-09-93	13	930	25.2	6.57	7.44							
03-10-93	14	900	24.8	6.49	7.74							
03-11-93	15	900	25.3	6.89	7.38	47.6	102.6	373	0.00	0.00		
03-12-93	16	800	24.5	6.75	7.87							
03-13-93	17	1600	24.9	6.67	7.60							
03-14-93	18	1500	24.9	6.73	7.64							
03-15-93	19	900	24.7	6.74	7.75							
03-16-93	20	900	25.2	6.78	7.73							
03-17-93	21	900	25.5	6.73	7.34	34.0	102.6	573	0.00	0.00	0.018	0.00005
03-18-93	22	1030	25.4	6.77	7.50							
03-19-93	23	1000	25.7	7.10	7.46							
03-20-93	24	1100	26.9	6.73	7.45							
03-21-93	25	1230	25.6	6.72	7.84							
03-22-93	26	900	25.1	6.73	7.79							
03-23-93	27	900	25.0	6.71	7.75							
03-24-93	28	900	25.4	6.65	7.60							
03-25-93	29	900	25.2	6.65	7.64	27.2	85.5	371	0.00	0.00	0.000	0.00000
03-26-93	30	800	24.9	6.26	7.80							
03-27-93	31	1000	25.3	6.27	7.58							
03-28-93	32	1000	25.6	6.40	7.57							
03-29-93	33	1100	25.8	6.45	7.54							
03-30-93	34	1100	25.6	6.40	7.53							
03-31-93	35	1000	25.5	6.51	5.95	34.0	85.5	358	0.00	0.00	0.000	0.00000
04-01-93	36	1000	24.8	6.55	7.89							
04-02-93	37	1000	24.8	6.55	8.04							
04-03-93	38	1100	24.8	6.54	8.13							
04-04-93	39	1300	24.8	6.52	8.32							
04-05-93	40	900	24.8	6.49	8.28							
04-06-93	41	1100	24.7	6.49	8.09							

04-07-93	42	900	25.1	6.59	8.11	34.0	85.5	360	0.00	0.00	0.00000
04-08-93	43	900	25.2	6.60	7.97						
04-09-93	44	900	25.3	6.61	7.80						
04-10-93	45	1000	25.4	6.54	7.58						
04-11-93	46	800	24.8	6.59	8.02						
04-12-93	47	1000	25.2	6.61	7.93						
04-13-93	48	900	25.0	6.59	7.68						
04-14-93	49	600	25.0	6.61	7.37						
04-15-93	50	900	25.3	6.61	7.47						
04-16-93	51	1000	25.5	6.62	8.42						
04-17-93	52	1000	25.3	6.62	7.55						
04-18-93	53	1000	24.8	6.69	7.67						
04-19-93	54	900	25.1	6.62	7.72						
04-20-93	55	900	25.4	6.62	7.82						
04-21-93	56	1000	25.4	6.64	7.28						
04-22-93	57	900	24.8	6.65							
04-23-93	58	900	24.8	6.69	7.03	34.0	102.6	343	0.00	0.00000	0.00000
04-24-93	59	1000	25.1	6.64	7.71						
04-25-93	60	800	25.2	6.61	7.76						
04-26-93	61	900	25.3	6.62	7.05						
04-27-93	62	1000	24.4	6.71	7.65						
04-28-93	63	900	25.0	6.64	7.21						
04-29-93	64	1000	25.0	6.66	7.44						
04-30-93	65	1000	25.2	6.67	7.45	34.0	102.6	349	0.00	0.024	0.00006
05-01-93	66	1000	25.4	6.66	7.76						
05-02-93	67	1000	25.4	6.66	7.55						
05-03-93	68	1000	25.4	6.67	7.67						
05-04-93	69	1000	25.5	6.69	7.22						
05-05-93	70	900	25.5	6.68	6.85						
05-06-93	71	1000	25.1	6.66	6.88	34.0	85.5	359	0.00	0.037	0.00010
05-07-93	72	900	24.9	6.71	6.71						
05-08-93	73	1640	25.2	6.59	4.50						
05-09-93	74	1440	25.1	6.72	5.22						
05-10-93	75	1000	24.9	6.63	6.48						
05-11-93	76	900	25.0	6.65	6.96						
05-12-93	77	1000	25.1	6.69	6.53						
05-13-93	78	1000	25.0	6.70	6.87	34.0	85.5	351	0.00	0.00000	0.00000
05-14-93	79	800	24.8	6.74	6.77						
05-15-93	80	800	24.9	6.74	7.20						
05-16-93	81	1100	25.1	6.72	7.29						
05-17-93	82	900	24.9	6.64	7.23						
05-18-93	83	1000	24.9	6.66	7.26						
05-19-93	84	1000	25.2	6.76	6.82						
05-20-93	85	900	25.3	6.73	6.75	34.0	102.6	355	0.00	0.069	0.00021
05-21-93	86	900	24.9	6.71	6.73						
05-22-93	87	800	24.7	6.83	6.92						
05-23-93	88	1000	24.6	6.78	6.98						
05-24-93	89	800	24.7	6.70	6.76						
05-25-93	90	1000	24.9	6.85	6.33						
05-26-93	91	900	24.9	6.78	6.96						
05-27-93	92	900	24.8	6.62	6.95						
05-28-93	93	1000	24.9	6.65	6.81	34.0	102.6	357	0.00	0.084	0.00020
05-29-93	94	1200	25.1	6.64	7.06						
05-30-93	95	900	24.9	6.72	6.49						





09-16-93	204	930	25.1	6.70	6.46	34.0	102.6	373	0.00	0.00	0.00000
09-17-93	205	930	24.6	6.66	6.61						
09-18-93	206	800	24.8	6.77	6.86						
09-19-93	207	1300	24.6	6.72	7.05						
09-20-93	208	930	24.5	6.68	6.93						
09-21-93	209	930	25.9	6.80	6.19						
09-22-93	210	900	25.2	6.61	6.49						
09-23-93	211	930	25.1	6.69	6.83	34.0	102.6	403	0.00	0.00	0.00000
09-24-93	212	1000	25.2	6.70	6.58						
09-25-93	213	900	25.0	6.72	6.91						
09-26-93	214	2100	25.5	6.78	6.94						
09-27-93	215	1000	25.3	6.77	6.64						
09-28-93	216	900	24.8	6.75	6.91						
09-29-93	217	930	24.8	6.72	6.96	34.0	102.6	400	0.00	0.00	0.00001
09-30-93	218	1300	24.6	6.55	6.82						
10-01-93	219	1100	24.2	6.65	8.01						
10-02-93	220	830	24.7	6.71	6.95						
10-03-93	221	830	24.9	6.73	6.76						
10-04-93	222	1000	24.5	6.69	6.94						
10-05-93	223	1000	24.9	6.65	6.69						
10-06-93	224	930	24.5	6.77	7.13						
10-07-93	225	930	24.9	6.82	6.91	40.8	102.6	389	0.00	0.00	0.00000
10-08-93	226	1000	24.9	6.77	7.00						
10-09-93	227	1130	24.9	6.77	7.04						
10-10-93	228	1130	24.6	6.77	7.16						
10-11-93	229	1600	24.6	6.79	7.19						
10-12-93	230	1000	24.5	6.74	7.06						
10-13-93	231	930	24.8	6.76	6.99						
10-14-93	232	1000	24.6	6.74	6.98	34.0	102.6	384	0.00	0.00	0.00000
10-15-93	233	1000	24.8	6.67	6.91						
10-16-93	234	1230	24.7	6.67	6.98						
10-17-93	235	1030	24.8	6.73	6.96						
10-18-93	236	1000	24.7	6.71	6.94						
10-19-93	237	900	24.8	6.67	7.01						
10-20-93	238	1000	24.8	6.75	7.17						
10-21-93	239	1000	24.8	6.76	7.01	34.0	102.6	394	0.00	0.00	0.00000
10-22-93	240	800	24.6	6.81	6.79						
10-23-93	241	700	24.3	6.82	7.32						
10-24-93	242	800	24.4	6.79	7.01						
10-25-93	243	1000	24.5	6.65	6.67						
10-26-93	244	1000	24.7	6.67	7.21						
10-27-93	245	1000	24.4	6.76	7.12						
10-28-93	246	1000	24.9	6.77	6.90	34.0	102.6	378	0.00	0.00	0.00012
10-29-93	247	1230	24.7	6.78	6.74						
10-30-93	248	700	25.0	6.82	6.91						
10-31-93	249	800	24.7	6.87	6.89						
11-01-93	250	930	24.4	6.76	6.90						
11-02-93	251	930	24.8	6.79	6.81						
11-03-93	252	1000	25.0	6.74	6.66						
11-04-93	253	1000	24.9	6.70	6.75	34.0	102.6	389	0.00	0.00	0.00000
11-05-93	254	1000	25.2	6.78	6.72						
11-06-93	255	600	25.2	6.70	6.71						
11-07-93	256	1000	25.0	6.74	6.67						
11-08-93	257	1000	24.8	6.76	6.81						

11-09-93	258	1000	24.7	6.74	6.85	34.0	102.6	377	0.00	0.00	0.00000
11-10-93	259	1000	24.7	6.70	6.79						
11-11-93	260	1100	24.7	6.74	6.72						
11-12-93	261	1000	24.9	6.71	6.61						
11-13-93	262	1230	24.9	6.75	6.57						
11-14-93	263	900	25.0	6.73	6.57						
11-15-93	264	1000	25.1	6.71	6.47						
11-16-93	265	1000	25.0	6.66	6.60						
11-17-93	266	1200	25.2	6.66	5.88						
11-18-93	267	1000	24.9	6.73	6.61	34.0	102.6	371	0.00	0.019	0.00006
11-19-93	268	1000	24.9	6.75	6.56						
11-20-93	269	830	24.9	6.72	6.59						
11-21-93	270	1300	24.6	6.71	6.80						
11-22-93	271	930	24.6	6.71	6.79						
11-23-93	272	1000	24.7	6.69	6.82						
11-24-93	273	1300	24.7	6.80	6.18	34.0	102.6	384	0.00	0.049	0.00017
11-25-93	274	900	24.7	6.77	6.76						
11-26-93	275	1200	24.6	6.70	6.82						
11-27-93	276	1100	24.8	6.74	6.67						
11-28-93	277	1100	25.2	6.72	6.49						
11-29-93	278	600	24.2	7.35	7.19						
MEAN											
MINIMUM	25.0		25.0	6.70	6.87	34.9	100.0	374	0.00	0.00	0.00005
MAXIMUM	24.0		24.0	6.26	4.50	27.2	85.5	343	0.00	0.00	0.00000
Std Dev	26.9		26.9	7.35	8.42	47.6	102.6	573	0.00	0.00	0.00021
N	0.31		0.31	0.114	0.574	3.78	6.11	38.6	0.000	0.000	0.00064
	278		278	278	277	40	40	39	38	37	37

TANK No. 11  
TANK CONCENTRATION: 10% GROUNDWATER (WELL CC-33B)  
DEN EXPOSURE: 10 mg/L

Date	Test Day	Time (Military)	Temperature (Celsius)	pH	Dissolved Oxygen (mg/L)	Alkalinity (mg/L as CaCO3)	Hardness (mg/L as CaCO3)	Conductivity (umohs/cm)	Total Residual Chlorine (mg/L)	Free Available Chlorine (mg/L)	Total Ammonia- Nitrogen (mg/L)	Total Unionized Ammonia- Nitrogen (mg/L)
02-25-93	1	1500	24.5	6.48	7.50							
02-26-93	2	1000	23.9	6.64	7.57							
02-27-93	3	1000	24.4	6.82	7.33							
02-28-93	4	1100	24.8	6.88	7.31	34.0	102.6					
03-01-93	5	930	24.7	6.60	7.14							
03-02-93	6	1000	25.5	6.62	6.91							
03-03-93	7	1000	25.8	6.66	7.67							
03-04-93	8	1000	25.0	6.69	7.63							
03-05-93	9	800	25.4	6.69	7.40							
03-06-93	10	1000	24.8	6.52	7.66	34.0	102.6	461				
03-07-93	11	1100	24.8	6.30	7.71							
03-08-93	12	900	24.9	6.40	7.65							
03-09-93	13	930	25.2	6.57	7.40							
03-10-93	14	900	24.8	6.49	7.56							
03-11-93	15	900	25.3	6.90	7.40	47.6	102.6	378	0.00	0.00		
03-12-93	16	800	24.5	6.75	7.86							
03-13-93	17	1600	24.8	6.67	7.59							
03-14-93	18	1500	24.9	6.73	7.62							
03-15-93	19	900	24.7	6.74	7.65							
03-16-93	20	900	25.2	6.79	7.71						0.029	0.00009
03-17-93	21	900	25.5	6.73	7.29	34.0	102.6	565	0.00	0.00		
03-18-93	22	1030	25.4	6.78	7.43							
03-19-93	23	1000	25.7	7.11	7.49							
03-20-93	24	1100	26.9	6.73	7.43							
03-21-93	25	1230	25.6	6.72	7.82							
03-22-93	26	900	25.1	6.73	7.73							
03-23-93	27	900	25.0	6.71	7.75							
03-24-93	28	900	25.3	6.65	7.54							
03-25-93	29	900	25.1	6.65	7.63	27.2	85.5	373	0.00	0.00	0.000	0.00000
03-26-93	30	800	24.9	6.25	7.78							
03-27-93	31	1000	25.3	6.27	7.55							
03-28-93	32	1000	25.6	6.38	7.50							
03-29-93	33	1100	25.7	6.45	7.38							
03-30-93	34	1100	25.5	6.40	7.58							
03-31-93	35	1000	25.5	6.48	5.78							
04-01-93	36	1000	24.8	6.53	7.68	34.0	85.5	358	0.00	0.00	0.000	0.00000
04-02-93	37	1000	24.7	6.51	7.84							
04-03-93	38	1100	24.8	6.53	7.90							
04-04-93	39	1300	24.7	6.46	8.08							
04-05-93	40	900	24.7	6.44	8.16							
04-06-93	41	1100	24.6	6.47	8.00							



04-07-93	42	900	25.0	6.58	8.12	34.0	85.5	361	0.00	0.00	0.00000
04-08-93	43	900	25.2	6.60	7.95						
04-09-93	44	900	25.2	6.58	7.80						
04-10-93	45	1000	25.3	6.53	7.54						
04-11-93	46	800	24.8	6.58	8.00						
04-12-93	47	1000	25.2	6.60	7.79						
04-13-93	48	900	25.0	6.57	7.61						
04-14-93	49	600	25.0	6.61	7.36						
04-15-93	50	900	25.3	6.61	7.43						
04-16-93	51	1000	25.5	6.60	8.22	34.0	85.5	352	0.00	0.028	0.00007
04-17-93	52	1000	25.3	6.59	7.40						
04-18-93	53	1000	24.8	6.66	7.52						
04-19-93	54	900	25.1	6.58	7.63						
04-20-93	55	900	25.4	6.58	7.68						
04-21-93	56	1000	25.4	6.61	7.40						
04-22-93	57	900	24.9	6.61		34.0	102.6	345	0.00	0.000	0.00000
04-23-93	58	900	24.8	6.63	7.16						
04-24-93	59	1000	25.1	6.62	7.64						
04-25-93	60	800	25.2	6.60	7.79						
04-26-93	61	900	25.3	6.60	7.07						
04-27-93	62	1000	24.4	6.71	7.74						
04-28-93	63	900	25.0	6.64	7.34						
04-29-93	64	1000	25.0	6.65	7.34	34.0	102.6	350	0.00	0.023	0.00006
04-30-93	65	1000	25.2	6.66	7.59						
05-01-93	66	1000	25.4	6.64	8.04						
05-02-93	67	1000	25.4	6.63	7.80						
05-03-93	68	1000	25.4	6.63	7.89						
05-04-93	69	1000	25.5	6.65	7.27						
05-05-93	70	900	25.5	6.66	7.01						
05-06-93	71	1000	25.1	6.66	7.07	34.0	85.5	363	0.00	0.021	0.00005
05-07-93	72	900	24.9	6.69	7.18						
05-08-93	73	1640	25.2	6.57	5.25						
05-09-93	74	1440	25.1	6.68	5.82						
05-10-93	75	1000	24.9	6.62	6.89						
05-11-93	76	900	25.0	6.64	7.35						
05-12-93	77	1000	25.1	6.69	6.87						
05-13-93	78	1000	25.1	6.70	7.09	34.0	102.6	354	0.00	0.000	0.00000
05-14-93	79	800	24.8	6.72	7.01						
05-15-93	80	800	24.9	6.73	7.41						
05-16-93	81	1100	25.1	6.71	7.60						
05-17-93	82	900	24.9	6.62	7.49						
05-18-93	83	1000	24.9	6.64	7.53						
05-19-93	84	1000	25.2	6.74	7.15						
05-20-93	85	900	25.3	6.70	6.90	34.0	102.6	356	0.00	0.057	0.00017
05-21-93	86	900	24.9	6.68	6.92						
05-22-93	87	800	24.6	6.82	7.16						
05-23-93	88	1000	24.5	6.76	7.05						
05-24-93	89	800	24.7	6.68	7.01						
05-25-93	90	1000	24.8	6.82	6.71						
05-26-93	91	900	24.9	6.78	7.05						
05-27-93	92	900	24.9	6.62	6.90	34.0	102.6	336	0.00	0.083	0.00020
05-28-93	93	1000	25.0	6.66	6.86						
05-29-93	94	1200	25.2	6.67	7.09						
05-30-93	95	900	25.0	6.73	6.41						



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09-16-93	204	930	25.2	6.70	6.48	34.0	102.6	390	0.00	0.00	0.0000
09-17-93	205	930	24.5	6.66	6.57						
09-18-93	206	800	24.8	6.77	6.83						
09-19-93	207	1300	24.6	6.72	7.04						
09-20-93	208	930	24.5	6.68	6.95						
09-21-93	209	930	26.0	6.80	6.30						
09-22-93	210	900	25.3	6.62	6.47						
09-23-93	211	930	25.1	6.69	6.80	34.0	102.6	402	0.00	0.00	0.00000
09-24-93	212	1000	25.2	6.70	6.56						
09-25-93	213	900	25.1	6.72	6.90						
09-26-93	214	2100	25.6	6.78	6.93						
09-27-93	215	1000	25.4	6.77	6.67						
09-28-93	216	900	24.8	6.75	6.94						
09-29-93	217	930	24.8	6.72	6.93						
09-30-93	218	1300	24.7	6.56	6.78						
10-01-93	219	1100	24.2	6.67	7.89	34.0	102.6	399	0.00	0.00	0.00001
10-02-93	220	830	24.3	6.71	6.90						
10-03-93	221	830	25.0	6.72	6.89						
10-04-93	222	1000	24.5	6.69	6.92						
10-05-93	223	1000	24.9	6.65	6.55						
10-06-93	224	930	24.5	6.77	7.09						
10-07-93	225	930	24.9	6.82	6.95	40.8	102.6	398	0.00	0.00	0.00000
10-08-93	226	1000	24.9	6.77	6.91						
10-09-93	227	1130	24.9	6.77	6.97						
10-10-93	228	1130	24.6	6.77	7.13						
10-11-93	229	1600	24.6	6.79	7.15						
10-12-93	230	1000	24.5	6.74	7.05						
10-13-93	231	930	24.7	6.76	6.96						
10-14-93	232	1000	24.6	6.74	6.95	34.0	102.6	395	0.00	0.00	0.00000
10-15-93	233	1000	24.7	6.67	6.91						
10-16-93	234	1230	24.7	6.67	6.88						
10-17-93	235	1030	24.8	6.73	6.82						
10-18-93	236	1000	24.7	6.71	6.83						
10-19-93	237	900	24.7	6.67	6.87						
10-20-93	238	1000	24.7	6.75	7.07						
10-21-93	239	1000	24.8	6.76	6.95	34.0	102.6	398	0.00	0.00	0.00000
10-22-93	240	800	24.6	6.78	6.91						
10-23-93	241	700	24.3	6.82	7.21						
10-24-93	242	800	24.4	6.75	7.12						
10-25-93	243	1000	24.4	6.66	6.47						
10-26-93	244	1000	24.6	6.67	6.90						
10-27-93	245	1000	24.3	6.76	6.91						
10-28-93	246	1000	24.8	6.77	6.77	34.0	102.6	382	0.00	0.00	
10-29-93	247	1230	24.6	6.78	6.70						
10-30-93	248	700	24.9	6.82	6.89						
10-31-93	249	800	24.6	6.87	6.84						
11-01-93	250	930	24.3	6.76	6.80						
11-02-93	251	930	24.7	6.79	6.91						
11-03-93	252	1000	24.9	6.74	6.77						
11-04-93	253	1000	24.9	6.70	6.81	34.0	102.6	396	0.00	0.00	0.00000
11-05-93	254	1000	25.1	6.78	6.71						
11-06-93	255	600	25.2	6.70	6.68						
11-07-93	256	1000	24.9	6.74	6.63						
11-08-93	257	1000	24.8	6.75	6.80						

11-09-93	258	1000	24.6	6.74	6.82	34.0	102.6	387	0.00	0.003	0.00001
11-10-93	259	1000	24.7	6.70	6.70						
11-11-93	260	1100	24.6	6.74	6.74						
11-12-93	261	1000	24.9	6.71	6.57						
11-13-93	262	1230	24.9	6.75	6.56						
11-14-93	263	900	25.0	6.74	6.53						
11-15-93	264	1000	25.1	6.71	6.47						
11-16-93	265	1000	25.0	6.66	6.55						
11-17-93	266	1200	25.2	6.66	5.93						
11-18-93	267	1000	24.8	6.73	6.63	34.0	102.6	384	0.00	0.019	0.00006
11-19-93	268	1000	24.8	6.75	6.67						
11-20-93	269	830	24.8	6.72	6.62						
11-21-93	270	1300	24.5	6.71	6.82						
11-22-93	271	930	24.5	6.71	6.78						
11-23-93	272	1000	24.6	6.69	6.92						
11-24-93	273	1300	24.5	6.80	6.28	34.0	102.6	393	0.00	0.044	0.00015
11-25-93	274	900	24.5	6.77	6.79						
11-26-93	275	1200	24.4	6.70	6.88						
11-27-93	276	1100	24.7	6.74	6.74						
11-28-93	277	1100	25.2	6.72	6.45						
11-29-93	278	600	24.0	7.36	7.43						

MEAN	25.0	6.69	6.90	35.0	100.5	378	0.00	0.00	0.00	0.018	0.00005
MINIMUM	23.9	6.25	5.25	27.2	85.5	336	0.00	0.00	0.00	0.000	0.00000
MAXIMUM	26.9	7.38	8.22	47.6	102.6	565	0.00	0.00	0.00	0.111	0.00021
Std Dev	0.34	0.114	0.533	3.58	5.66	37.7	0.000	0.000	0.000	0.0256	0.000064
N	278	278	277	40	40	39	38	38	38	37	37

TANK No. 12  
TANK CONCENTRATION: 10% GROUNDWATER (WELL CC-33B)  
DEN EXPOSURE: 10 mg/L

Date	Test Day	Time (Military)	Temperature (Celsius)	pH	Dissolved Oxygen (mg/L)	Alkalinity (mg/L as CaCO3)	Hardness (mg/L as CaCO3)	Conductivity (umohs/cm)	Total Residual Chlorine (mg/L)	Free Available Chlorine (mg/L)	Total Ammonia-Nitrogen (mg/L)	Total Unionized Ammonia-Nitrogen (mg/L)
02-25-93	1	1500	24.4	6.47	7.55							
02-26-93	2	1000	23.9	6.63	7.61							
02-27-93	3	1000	24.4	6.83	7.39							
02-28-93	4	1100	24.6	6.88	7.28	34.0	102.6					
03-01-93	5	930	24.7	6.60	7.15							
03-02-93	6	1000	25.5	6.62	6.97							
03-03-93	7	1000	25.8	6.66	7.67							
03-04-93	8	1000	25.1	6.70	7.64							
03-05-93	9	800	25.4	6.70	7.34			464				
03-06-93	10	1000	24.9	6.51	7.60	27.2	102.6					
03-07-93	11	1100	24.8	6.29	7.71							
03-08-93	12	900	24.9	6.39	7.59							
03-09-93	13	930	25.2	6.56	7.43							
03-10-93	14	900	24.8	6.49	7.42			380	0.00	0.00		
03-11-93	15	900	25.3	6.89	7.32	47.6	102.6					
03-12-93	16	800	24.5	6.75	7.84							
03-13-93	17	1600	24.8	6.67	7.53							
03-14-93	18	1500	24.8	6.73	7.49							
03-15-93	19	900	24.7	6.74	7.65							
03-16-93	20	900	25.2	6.79	7.67			568	0.00	0.00	0.028	0.00008
03-17-93	21	900	25.5	6.73	7.21	34.0	102.6					
03-18-93	22	1030	25.3	6.77	7.29							
03-19-93	23	1000	25.6	7.11	7.44							
03-20-93	24	1100	26.9	6.73	7.43							
03-21-93	25	1230	25.6	6.72	7.79							
03-22-93	26	900	25.0	6.72	7.77							
03-23-93	27	900	24.9	6.71	7.71							
03-24-93	28	900	25.3	6.65	7.57			372	0.00	0.00	0.000	0.00000
03-25-93	29	900	25.1	6.64	7.52	27.2	85.5					
03-26-93	30	800	24.9	6.25	7.75							
03-27-93	31	1000	25.2	6.27	7.51							
03-28-93	32	1000	25.6	6.38	7.47							
03-29-93	33	1100	25.7	6.45	7.39							
03-30-93	34	1100	25.5	6.39	7.59							
03-31-93	35	1000	25.5	6.46	5.76							
04-01-93	36	1000	24.8	6.50	7.66	34.0	85.5	359	0.00	0.00	0.000	0.00000
04-02-93	37	1000	24.7	6.51	7.72							
04-03-93	38	1100	24.8	6.53	7.90							
04-04-93	39	1300	24.7	6.46	7.99							
04-05-93	40	900	24.7	6.44	8.13							
04-06-93	41	1100	24.6	6.47	7.99							

04-07-93	42	900	25.0	6.58	8.06	34.0	85.5	357	0.00	0.00	0.00000
04-08-93	43	900	25.2	6.58	7.94						
04-09-93	44	900	25.3	6.57	7.80						
04-10-93	45	1000	25.3	6.53	7.52						
04-11-93	46	800	24.8	6.57	7.97						
04-12-93	47	1000	25.2	6.59	7.78						
04-13-93	48	900	25.0	6.56	7.59						
04-14-93	49	600	25.1	6.60	7.35						
04-15-93	50	900	25.3	6.58	7.36						
04-16-93	51	1000	25.5	6.58	8.16						
04-17-93	52	1000	25.3	6.58	7.33						
04-18-93	53	1000	24.9	6.65	7.41						
04-19-93	54	900	25.2	6.56	7.53	34.0	102.6	351	0.00	0.00	0.00006
04-20-93	55	900	25.4	6.56	7.56						
04-21-93	56	1000	25.4	6.61	7.31						
04-22-93	57	900	24.9	6.61		34.0	102.6	347	0.00	0.00	0.00000
04-23-93	58	900	24.8	6.63	7.08						
04-24-93	59	1000	25.1	6.60	7.59						
04-25-93	60	800	25.2	6.59	7.79						
04-26-93	61	900	25.3	6.60	7.08						
04-27-93	62	1000	24.4	6.70	7.70						
04-28-93	63	900	25.0	6.60	7.32						
04-29-93	64	1000	25.0	6.65	7.17	34.0	102.6	353	0.00	0.00	0.00008
04-30-93	65	1000	25.2	6.64	7.17						
05-01-93	66	1000	25.4	6.62	7.90						
05-02-93	67	1000	25.5	6.62	7.71						
05-03-93	68	1000	25.4	6.61	7.82						
05-04-93	69	1000	25.6	6.65	7.22						
05-05-93	70	900	25.5	6.66	7.16						
05-06-93	71	1000	25.1	6.65	7.09	34.0	85.5	364	0.00	0.00	0.00003
05-07-93	72	900	24.9	6.68	7.23						
05-08-93	73	1640	25.2	6.56	5.38						
05-09-93	74	1440	25.1	6.61	5.29						
05-10-93	75	1000	24.9	6.62	6.94						
05-11-93	76	900	25.0	6.64	7.36						
05-12-93	77	1000	25.1	6.66	6.90						
05-13-93	78	1000	25.0	6.69	7.15	34.0	102.6	354	0.00	0.00	0.00000
05-14-93	79	800	24.8	6.72	7.01						
05-15-93	80	800	24.8	6.73	7.41						
05-16-93	81	1100	25.1	6.71	7.61						
05-17-93	82	900	24.8	6.62	7.55						
05-18-93	83	1000	24.8	6.64	7.62						
05-19-93	84	1000	25.1	6.74	7.20						
05-20-93	85	900	25.3	6.69	6.96	34.0	102.6	359	0.00	0.00	0.00019
05-21-93	86	900	24.9	6.68	7.14						
05-22-93	87	800	24.6	6.81	7.33						
05-23-93	88	1000	24.5	6.74	7.17						
05-24-93	89	800	24.7	6.67	7.12						
05-25-93	90	1000	24.8	6.82	6.76						
05-26-93	91	900	24.9	6.78	7.13						
05-27-93	92	900	24.9	6.66	6.97	34.0	102.6	344	0.00	0.00	0.00016
05-28-93	93	1000	25.0	6.66	6.95						
05-29-93	94	1200	25.1	6.67	7.22						
05-30-93	95	900	25.0	6.73	6.60						







09-16-93	204	930	252	6.70	6.44	34.0	102.6	402	0.00	0.00	0.0000
09-17-93	205	930	246	6.66	6.50						
09-18-93	206	800	248	6.77	6.78						
09-19-93	207	1300	245	6.72	7.10						
09-20-93	208	930	244	6.68	6.87						
09-21-93	209	930	259	6.80	6.25						
09-22-93	210	900	252	6.61	6.48						
09-23-93	211	930	251	6.69	6.81	34.0	102.6	412	0.00	0.00	0.00000
09-24-93	212	1000	252	6.70	6.61						
09-25-93	213	900	250	6.72	6.92						
09-26-93	214	2100	256	6.78	7.01						
09-27-93	215	1000	253	6.77	6.73						
09-28-93	216	900	248	6.75	6.91						
09-29-93	217	930	248	6.72	6.91	34.0	102.6	407	0.00	0.00	0.00003
09-30-93	218	1300	246	6.56	6.91						
10-01-93	219	1100	242	6.66	8.09						
10-02-93	220	830	247	6.70	6.91						
10-03-93	221	830	249	6.72	6.71						
10-04-93	222	1000	245	6.69	6.92						
10-05-93	223	1000	249	6.65	6.68						
10-06-93	224	930	245	6.77	7.08						
10-07-93	225	930	249	6.82	6.97	40.8	102.6	407	0.00	0.00	0.00000
10-08-93	226	1000	249	6.77	7.01						
10-09-93	227	1130	249	6.77	7.04						
10-10-93	228	1130	246	6.77	7.14						
10-11-93	229	1600	246	6.79	7.28						
10-12-93	230	1000	245	6.74	7.12						
10-13-93	231	930	247	6.76	7.03						
10-14-93	232	1000	246	6.74	7.04	34.0	102.6	403	0.00	0.00	0.00000
10-15-93	233	1000	247	6.67	6.99						
10-16-93	234	1230	246	6.67	7.00						
10-17-93	235	1030	248	6.73	6.91						
10-18-93	236	1000	247	6.69	6.89						
10-19-93	237	900	247	6.67	7.03						
10-20-93	238	1000	247	6.75	7.21						
10-21-93	239	1000	247	6.76	7.04	34.0	102.6	405	0.00	0.00	0.00000
10-22-93	240	800	246	6.79	6.84						
10-23-93	241	700	243	6.80	7.27						
10-24-93	242	800	243	6.75	7.18						
10-25-93	243	1000	243	6.65	6.54						
10-26-93	244	1000	246	6.67	7.09						
10-27-93	245	1000	243	6.76	7.08						
10-28-93	246	1000	248	6.78	7.02	34.0	102.6	386	0.00	0.00	0.00016
10-29-93	247	1230	246	6.78	6.91						
10-30-93	248	700	249	6.82	7.00						
10-31-93	249	800	246	6.87	6.97						
11-01-93	250	930	243	6.76	7.00						
11-02-93	251	930	247	6.79	6.97						
11-03-93	252	1000	249	6.74	6.90						
11-04-93	253	1000	249	6.70	6.91	34.0	102.6	401	0.00	0.00	0.00000
11-05-93	254	1000	251	6.78	6.81						
11-06-93	255	600	252	6.70	6.69						
11-07-93	256	1000	249	6.74	6.75						
11-08-93	257	1000	248	6.75	6.90						

11-09-93	258	1000	24.7	6.74	6.94	34.0	102.6	387	0.00	0.00	0.00000
11-10-93	259	1000	24.7	6.70	6.82						
11-11-93	260	1100	24.6	6.74	6.84						
11-12-93	261	1000	24.8	6.72	6.72						
11-13-93	262	1230	24.9	6.75	6.69						
11-14-93	263	900	25.0	6.74	6.66						
11-15-93	264	1000	25.1	6.71	6.56						
11-16-93	265	1000	24.9	6.66	6.68						
11-17-93	266	1200	25.1	6.66	6.01						
11-18-93	267	1000	24.9	6.73	6.76	34.0	102.6	381	0.00	0.015	0.00004
11-19-93	268	1000	24.9	6.75	6.72						
11-20-93	269	830	24.9	6.72	6.58						
11-21-93	270	1300	24.5	6.71	6.99						
11-22-93	271	930	24.5	6.71	6.79						
11-23-93	272	1000	24.6	6.69	6.99	34.0	102.6	401	0.00	0.041	0.00014
11-24-93	273	1300	24.6	6.80	6.41						
11-25-93	274	900	24.6	6.77	6.91						
11-26-93	275	1200	24.4	6.70	7.07						
11-27-93	276	1100	24.7	6.74	6.84						
11-28-93	277	1100	25.2	6.72	6.59						
11-29-93	278	600	24.1	7.38	7.42						
MEAN			25.0	6.69	6.93	34.9	100.9	380	0.00	0.016	0.00004
MINIMUM			23.9	6.25	5.29	27.2	85.5	344	0.00	0.000	0.00000
MAXIMUM			26.9	7.38	8.16	47.6	102.6	568	0.00	0.110	0.00021
Std Dev			0.33	0.116	0.514	3.78	5.13	39.8	0.000	0.0248	0.000061
N			278	278	277	40	40	39	38	37	37

# APPENDIX 50

## ROUTINE WATER QUALITY CHEMICAL METHODS FOR ALL SAMPLES ANALYZED IN THE BIOMONITORING TRAILER AND AT THE UMD/WREC LABORATORY

Parameter	Method <sup>a</sup>
Alkalinity	Method 2320 B. Titration Method
Ammonia-nitrogen	Method 4500-NH <sub>3</sub> . Ammonia Selective Electrode Method
Chlorine	Method 4500-Cl G. DPD Colorimetric Method
Conductivity	Method 2510 B. Laboratory Method
Dissolved Oxygen	Method 4500-O G. Membrane Electrode Method
Hardness	Method 2340 C. EDTA Titrimetric Method
pH	Method 4500-H <sup>+</sup> B. Electrometric Method
Temperature	Method 2550 B. Laboratory and Field Methods

<sup>a</sup> All methods taken from Standard Methods (APHA et al., 1989).

APPENDIX 51

SCREENING-LEVEL ASSESSMENT OF THE NEAR- AND FAR-FIELD  
DILUTION OF THE SURFICIAL GROUNDWATER DISCHARGE  
FROM BEACH POINT INTO THE BUSH RIVER

# **FINAL REPORT - JOB 1437**

## **SCREENING-LEVEL ASSESSMENT OF THE NEAR-FIELD DILUTION OF GROUNDWATER DISCHARGES FROM THE BEACH POINT SITE**

**Prepared for:**  
**U.S. ARMY BIOMEDICAL RESEARCH AND DEVELOPMENT LABORATORY**  
**FORT DETRICK, BUILDING 568**  
**FREDERICK MD 21702-5010**

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**JULY, 1994**

## EXECUTIVE SUMMARY

This study was initiated to assess the potential impact to the Bush River due to contaminated groundwater emanating from the Army Proving Ground site in Harford County, Maryland. Towards this objective, an EPA-approved near-field model was adapted to the receiving-waters adjacent to the APG site. The model approach and input was developed to provide a conservative assessment of receiving water impacts. This analysis suggests a near-field dilution level of approximately 42:1 for the application of acute criteria and a near-field dilution level of approximately 168:1 for the application of chronic criteria. Thus, contaminants introduced into Bush River receiving-waters at a concentration of 42 ppb will be diluted locally to a concentration of approximately 1 ppb or less. By applying these dilution factors to the groundwater quality data from the APG site, near-field concentrations within the Bush River can be projected. These results indicate that Tables 8 and 9, none of the projected receiving water concentrations would exceed Maryland's current acute or chronic criteria.

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## 1. INTRODUCTION

### 1.1 Background

The U.S Army Aberdeen Proving Ground (APG) is located between the Bush River and the Upper Chesapeake Bay in Harford County, Maryland. Currently, the U.S. Army Biomedical Research and Development Laboratory (USABRDL) is conducting biomonitoring evaluation studies of groundwater contamination at the APG site. To complement such studies, the USABRDL requires information regarding potential impacts of such groundwater contamination on Bush River water quality. Such impacts depend upon the ability of these receiving waters to mix and dilute contaminants introduced by groundwater sources. Accordingly, Najarian Associates, Inc. was contracted by the USABRDL to conduct preliminary model studies of groundwater-plume dilution in the Bush River.

The initial dilution of groundwater-discharge plumes depends, in part, upon the physical characteristics of both the source and the ambient receiving waters. These characteristics include the quantity/quality of the discharge, the geometrical configuration of the source, the ambient current speed, the ambient density stratification, and the water depth. These latter three factors control the near-field mixing of discharged constituents with surrounding receiving-waters, primarily through the mechanisms of plume buoyancy and initial discharge momentum. Typically, all such factors are incorporated into plume-dilution models, including simplified "screening-level" approaches.

## 1.2 Objectives

The basic goal of this study is to estimate, using EPA-approved screening-level

techniques, the initial ("near-field") dilution and flushing rate ("far-field" dilution) of groundwater discharge plumes within the adjacent surface waters. Such an assessment, when combined with relevant discharge concentration data, would provide first-order estimates of resulting near-field concentrations — receiving-water concentrations that would be expected over relatively short distances from the discharge site (e.g., ones, tens and hundreds of meters) and over short time periods (e.g., seconds and minutes). Our second objective is to compute such concentrations for selected toxic constituents and to compare the results to available baseline data. As a result, potential water quality impacts may be quantified. A third study goal is to assess the applicability of a "regulatory mixing zone" — a localized discharge zone in which local water quality standards may be exceeded. Such zones are routinely allowed for wastewater treatment plant discharges. If applicable to the subject groundwater-discharge plume, a mixing zone may allow for local exceedences of water quality standards.

## 1.3 Study Area

The goals and procedures outlined above are based on relevant characteristics of the study area. Surface elevations at the APG Beach Point site lie approximately 14.5 feet above sea level. An unsaturated zone occurs from elevation 14.5 ft down and at depths as shallow as 1 ft. The site is underlain by an impermeable clay lens located at a depth ranging from approximately 70 feet to 120 ft. A lower confined aquifer known as the Canal Creek Aquifer occurs below the upper confining unit.

The Bush River is a relatively small and shallow tributary estuary located on the western shore of the Upper Chesapeake Bay (Figure 1). The Bush River has a length of



approximately 14 km. Bush River MLW depths generally increase from an approximate 0.9-1.5 m range (near the head) to a 2.7-4.0 m range (near the mouth). The average Mean-Low-Water (MLW) depth is approximately 2 m. The average annual freshwater

discharge to the Bush River from its 316-km<sup>2</sup> drainage area is only about 4.7 m<sup>3</sup>/sec (Pritchard, 1976).

Bush River tides are predominantly semi-diurnal (NOAA, 1978), with a mean range at Pond Point of 0.4 m and a spring range of approximately 0.5 m (NOS, 1993a). Inside the entrance to the Bush River, about 2 miles south of Beach Point, average maximum tidal current speeds are approximately 0.3 m/sec (1.0 ft/sec; NOS, 1993).

The MLW volume of the Bush River is approximately  $6.0 \times 10^7$  m<sup>3</sup>; the inter-tidal volume (i.e., the "tidal prism") is about  $1.2 \times 10^7$  m<sup>3</sup> (Pritchard, 1976). Thus, the inter-tidal volume comprises a relatively large fraction (approximately 20%) of the River's MLW volume. In contrast, the mean runoff volume per day ( $4.1 \times 10^5$  m<sup>3</sup>/day) corresponds to a relatively small fraction of the River's MLW volume. Pritchard (1976) estimates that the MLW volume corresponds to approximately 150 days of mean freshwater inflow.

Due to its relatively small areal extent, depth, and freshwater inflow, the Bush River typically exhibits relatively small horizontal and vertical salinity gradients (Carter, 1976). For example, observations of system-wide salinity variations of only 3 ppt are reported in the Bush River (Martin Marietta, 1986; Carter, 1976). The longitudinal salinity difference is controlled primarily by the adjacent Chesapeake Bay salinities and secondarily by freshwater inflows to the Bush River from Otter Point Creek (Carter, 1976). Consequently, Bush River salinities do not always decrease monotonically in a

landward direction. Intratidal variations of Bush River salinities range from approximately 0.5 ppt near the mouth to near zero at the head (Carter, 1976).

Susquehanna River inflows to the Upper Chesapeake Bay influence the salinity distribution and circulation of the Bush River and other small tributary estuaries (Pritchard, 1976). As noted by Pritchard (1969), salinities of these embayments are controlled largely by the relatively low salinities of the Upper Bay and by Upper Bay variability. For example, Martin Marietta (1986) reports observations of Bush River salinities varying from 0.7 ppt (at the River's head-of-tide) to 3.7 ppt (at River mouth), consistent with prevailing local Bay salinities. However, the salinity of the Upper Bay and its tributaries also varies in response to seasonal changes in Susquehanna River flows, as described by Pritchard (1976).

During the autumn, when Susquehanna River flows are relatively low, Upper Chesapeake Bay salinities are constant or slowly increasing. At this time, the local freshwater inflow to the Bush River may be sufficient to set up an estuarine type gravitational circulation, with a net outflow of fresher surface waters and net inflow of more saline bottom waters. During the spring freshet, when salinities of the Upper Bay decrease over time, corresponding salinities of the tributary embayments (e.g., the Bush River) are relatively high. Consequently, a reverse estuarine circulation pattern may develop, with a net bottom outflow of more saline water from the River to the Bay proper, and a net surface inflow from the Bay proper into the River. Such seasonal gravitational circulation patterns enhance the flushing of the Bush River and other tributary embayments. Thus, the available far-field dilution would be greater at these times.

The Bush River at the Beach Point site is classified as a *Designated Use II: Shellfish Harvesting Waters* (COMAR 26.08.02.02B) — an actual or potential area for shellfish

propagation. Approximately one mile upstream from Beach Point, the Bush River classification changes to *Designated Use I: Water Contact Recreation, and Protection of Aquatic Life* (i.e., the basic swimmable/fishable classification).

Toxic water quality conditions in the Bush River are reported in a recent study of contaminants in Chesapeake Bay/Tributary sediments conducted by the Maryland Department of the Environment (Eskin et al., 1994). The MDE's toxics monitoring program includes a Bush River sampling station near Gum Point (Figure 1, 39°26'06"N, 76°14'36"W), approximately 5 km (3 miles) north of the Beach Point site. Annual (1988-91) sediment metals concentrations for this stations are reproduced below in Table 1; individual observations of sediment PAH and TOC for 1991 are reproduced in Table 2. In the tables, both the No Observable Effect Level (NOEL) and the Probable Effects Level (PEL) are listed for each parameter, where available. Such levels provide guidance regarding the potential toxicity of these parameters (MacDonald, 1993).

As indicated in the MDE report, most sediment concentrations observed in the Bush River fall above the NOEL but below the PEL. Thus, toxic effects due to each trace metal are unlikely (individually). However, compared to other tributary stations, the Bush River Nickel levels are somewhat high.

Where sediment quality guidelines are available, the data also suggest that toxicity due to individual PAH and TOC compounds is unlikely. In fact, most Bush River PAH concentrations observed in the MDE's 1991 survey fall below the corresponding NOELs.



TABLE 1: SEDIMENT METAL CONCENTRATIONS IN THE BUSH RIVER

Parameter	Guideline Limits (ppm)		Observed Concentrations (ppm)			
	NOEL	PEL	1988	1989	1990	1991
As	8	64	34.37	45.80	38.30	19.70
Cd	1	7.5	0.01	0.15	0.40	0.50
Cr	33	240	68.92	69.00	82.00	59.00
Cu	28	270	43.32	45.00	47.50	40.00
Pb	21	160	42.25	66.00	42.60	54.00
Hg	0.1	1.4	0.099	0.244	0.150	0.190
Ni	—	—	53.79	57.00	47.10	52.00
Zn	68	300	205.0	216.0	222.3	189.0

TABLE 2: SEDIMENT PAH AND TOC DATA FOR THE BUSH RIVER

Parameter	Guideline Limits (ppb)		Observed Concentrations (ppb)
	NOEL	PEL	
anthracene	85	740	75.0
fluoranthene	380	3,200	24.4
pyrene	—	—	224.9
benzo(A)anthracene	160	1,300	75.0
benzo(B)fluoranthene	—	—	187.4
benzo(K)fluoranthene	—	—	56.2
benzo(A)pyrene	230	2,500	112.5
benzo(G, H, 1)perylene	—	—	150.0

## 2. NEAR-FIELD MODEL STUDY

### 2.1 Approach

In this preliminary assessment, the impact of groundwater emanating from the APG site was evaluated based on the potential dilution available within the Bush River. Within the near-field, it is postulated that a groundwater plume intersects the channel of the Bush River and seeps into this River as a submerged buoyant plume. Based on the available geologic information about the APG site, it is also postulated that the discharge from the surface aquifer is limited to a relatively narrow band that parallels the interface between the Bush River and the subject APG site. As this groundwater plume is less dense (less saline) than the adjacent estuarine water, it would rise and subsequently mix with the ambient receiving-waters. Thus, it is diluted through mechanisms of buoyancy-based entrainment and mixing associated with ambient currents.

These same physical mechanisms are known to dilute effluent plumes discharged from the outfall diffusers of wastewater treatment plants (WWTP) and electrical generation facilities. Thus, the dilution of groundwater emanating from the APG site can be conceptualized as the dilution of the discharge from a line diffuser. This approach allows the near-field impact of this groundwater discharge to be simulated using established plume-dilution models that have been developed primarily for such outfall diffusers.

The limitations of this approach are twofold. First, most plume-dilution models also simulate momentum-based entrainment, a phenomenon that has a negligible effect upon the groundwater plume. Therefore, the port configuration on the

conceptualized line diffuser must be set to minimize initial momentum. Secondly, the conceptualization of the groundwater discharge surface as a line diffuser will concentrate the plume's impact within the near-field condition. As this effect reduces the dimensions of the near-field plume and the calculated levels of dilution, the model result will provide a conservative estimate of field conditions.

## **2.2 Near-Field Model Selection**

A series of EPA-approved, plume-dilution models for surface waters are documented in "Initial Mixing Characteristics of Municipal Ocean Discharges" by Muellenhoff et al. (EPA/600/3-85/073a, 1985) and by reviewed by Alam et al. (1982). These models provide a convenient and accepted choice of screening-level techniques. As noted above, such models are usually applied to discharges from line sources such as outfall diffuser manifold legs. In the present case, however, the subject discharges are emanating primarily from the adjacent stream bed.

While all EPA-approved plume models can be run, ULINE is preferred for dilution calculations since it is based directly on laboratory experiments and has proved it's usefulness in recent outfall studies conducted throughout the U.S.(e.g., Najarian Assoc., 1990). The ULINE model also neglects initial discharge momentum, consistent with the problem at hand.

Typically, outfall dilution studies are conducted under "critical" (minimum-dilution; Tetrattech, 1982) conditions. These conditions are defined as lowest 10th-percentile ambient currents, and highest 10th-percentile ambient density stratification conditions. However, Maryland regulations require that the acute toxicity criteria be applied under conditions of mean low water and "minimum daily averaged

1-hour tidal velocity" (COMAR 26.08.02.05C); chronic criteria are applied under conditions of mean water level and average tidal velocity (COMAR 26.08.02.05D).

Thus, the input data for the selected near-field model (ULINE) should reflect these required conditions.

To adapt ULINE to the study area, an input of site-specific data is required. Such model input data fall into three categories: (1) groundwater discharge parameters; (2) receiving-water parameters; and (3) outfall diffuser parameters. The selection of such parameters is described below:

### **2.3 Estimation of Groundwater Input Parameters**

Information relating the site's local geology and hydrogeologic conditions was obtained from previous studies by Jacobs Engineering Group and K-V Associates, Inc. (1994). These studies indicate that subsurface flows within the surficial aquifer are bounded by a sub-surface clay layer and that the portion of the aquifer underlying the Beach Point peninsula is both homogeneous and isotropic. On-site data indicates that the dominate, long-term groundwater flow direction would be down-gradient towards the Bush River.

Based on K-V Associates measurements and Jacobs Engineering calculations (Jacobs Engineering Group, 1994), the average saturated thickness of the surficial aquifer at the Beach Point peninsula is approximately 18.8 m (61.8 ft). Also, the Bush River frontage along the subject peninsula is approximately 448 m (1,470 ft). Approximately 366 m (1,200 ft) of frontage is directed in a northeast direction; approximately 82 m (270 ft) of the northern peninsula terminus is directed in a

northwest direction. Thus, the cross-section area of the saturated aquifer that parallels the Bush River is approximately 8,423 m<sup>2</sup> (90,846 ft<sup>2</sup>).

As conditions within the surficial aquifer are homogeneous and isotropic, horizontal velocity measurements at a single location may be used to evaluate the aquifer discharge. K-V Associates measured a 25-hour average horizontal velocity of 0.27 m/day (0.89 ft/day) at a 15-m deep well site located near the middle of the Beach Point Peninsula. This flow was directed 61.8° northeast of magnetic north, approximately 24° riverward from the main peninsula axis. Note that the above velocity measurement is a 24-hour average value (discounting short-term fluctuations due to tidal influences).

Jacobs Engineering estimates the groundwater seepage rate to be 0.0136 m<sup>3</sup>/sec (41,509 ft<sup>3</sup>/day). This estimate utilizes the directional component of the horizontal velocity that is *orthogonal* to the Bush River frontage. That is, the measured horizontal velocity (i.e., 0.27 m/day) is multiplied by a sin(24°) factor along the 366 m (1,200-ft) frontage:

$$\begin{aligned}\text{Discharge} &= (0.27 \text{ m/day velocity})(\sin 24^\circ)(18.8 \text{ m depth})(366 \text{ m frontage}) \\ &\quad + (0.27 \text{ m/day velocity})(18.8 \text{ m depth})(82 \text{ m frontage}) \\ &= 0.0136 \text{ m}^3/\text{sec}\end{aligned}$$

#### **2.4 Ambient Receiving Water Input**

Information relating the hydrographic conditions within the Bush River were obtained from a review of the NOAA Tidal Current Table data, NOAA navigation charts, and previous studies of the Bush River by Martin Marietta (1986).

## Ambient Current Velocity in Bush River

A review of the NOAA Tidal Current Table data at a location of 0.6 km southwest of Bush Point indicates that the maximum flood velocity is 0.305 m/sec (1.0 ft/sec or 0.6 knot). Assuming a pure sinusoidal tidal velocity distribution, having a 0.305 m/sec amplitude and 12.4 hour period, the "minimum daily average 1-hour tidal velocity was computed. That is, the assumed tidal current magnitude profile was averaged over a 1-hour window centered at slack tide (approximately hour 6.2). The resulting speed was estimated to be 0.04 m/sec (see Appendix A) . Thus, as a conservative estimate, an ambient current speed of 0.03 m/sec was input to the near-field model as a representative acute condition tidal current speed. Likewise, for the same sinusoidal profile, a tidal average speed was computed as 0.19 m/sec. This latter average is representative of the chronic condition speed.

## Ambient salinity and temperature in Bush River

A representative receiving-water salinity of 3 ppt is assumed in this study, consistent with the limited available data (e.g., Martin Marietta, 1986). Similarly, a temperature of 21° C is assumed for the Bush River. This salinity and temperature correspond to a receiving-water density of only 1.00031 g/cm<sup>3</sup>. Thus the selected values are conservative, inasmuch as only limited plume buoyancy will be available to dilute the discharges. Note that the assumed density of the groundwater discharges is 1.00024 g/cm<sup>3</sup> (i.e., only 0.007% lighter than the ambient receiving waters).

### Depth of discharge

Based on the most recent NOAA navigation chart for the Bush River, an average water depth of 1.5 m (5 ft) is assumed at the Bush River discharge site. However, a more conservative estimate of half this depth, 0.76 m (2.5 ft), is chosen as a representative model discharge depth. This selection reflects the fact that some of the discharge occurs along the shallow frontage of the peninsula.

### **2.5 Conceptualized Discharge Schematization**

As noted above, the 448-m-wide groundwater discharge plume at the Beach Point site seeps into the adjacent Bush River. Thus, this discharge is assumed to comprise a 448-m-long line source of buoyancy. By analogy, the corresponding plume in the Bush River is assumed to be discharged from a 295-port diffuser having a total length of 448 m and a "port" spacing of 1.5 m (5 ft). As noted by Roberts et al. (1989), the dilution level of a buoyancy-dominated plume is nearly independent of the number of ports, and depends primarily on *plume length* and buoyancy. The schematized diameter of each port is 1.2 m (4 ft). Such large diameter ports allowed momentum-related effects to be minimized. In addition, further testing showed that Model results are insensitive to port diameter (see section 2.7).

### **2.6 Near-Field Model Results**

Using information described above, an input file was constructed for the ULINE model and a series of simulation were conducted. *The results indicate that a near-field dilution ratio of 159:1 is appropriate for application of acute toxicity criteria. Similarly, model results indicate that a near-field dilution ratio of 1,006:1 is appropriate for application of chronic toxicity criteria.* Having limited buoyancy and initial

momentum, this near-field dilution is effected largely by the large discharge length of 427 m (1,400 ft) and ambient current field.

## **2.7 Model Sensitivity Analysis**

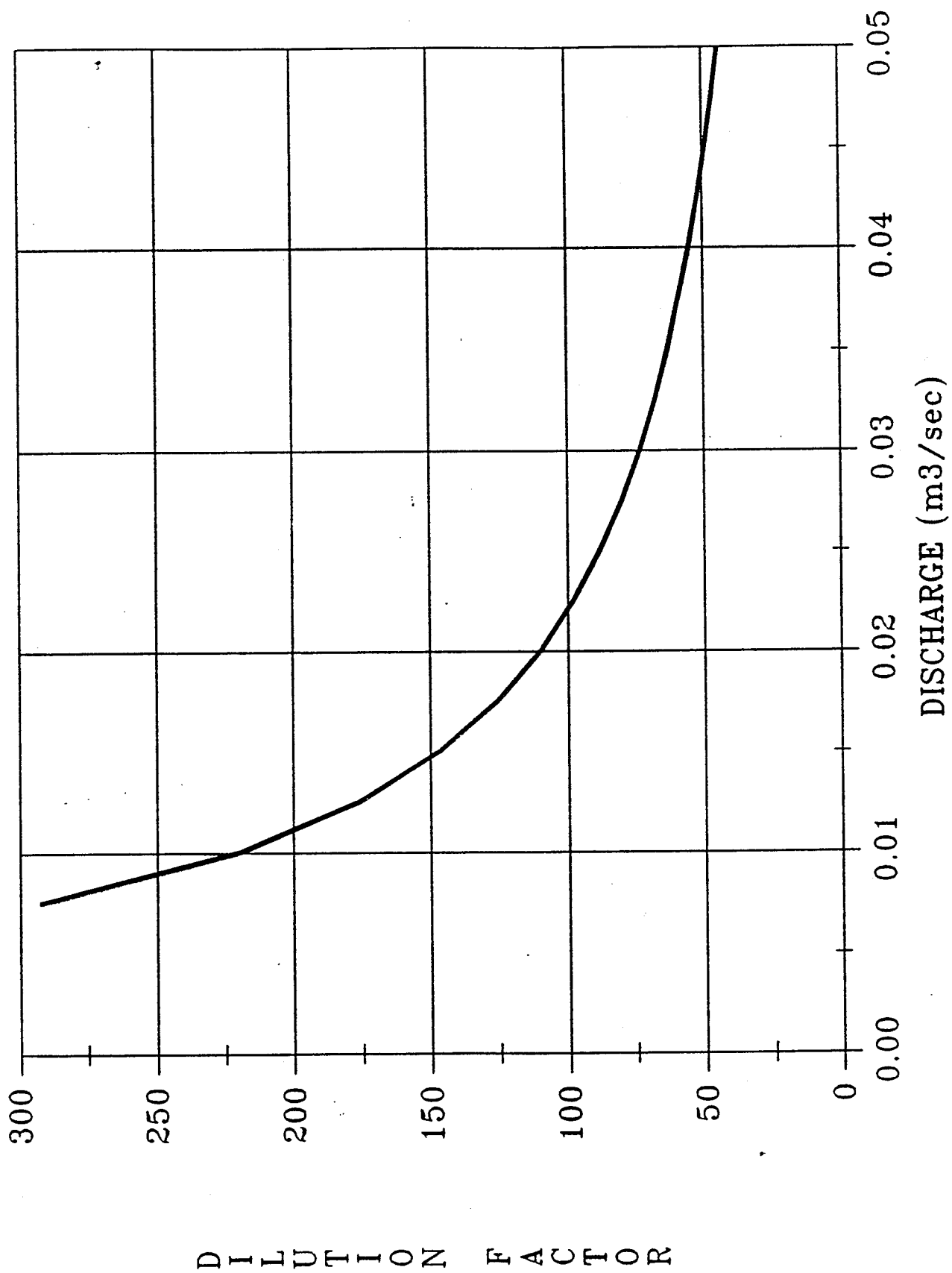
The accuracy of any model results depends, in part, upon the accuracy of selected input parameter values. Accordingly, a model sensitivity analysis was performed to evaluate effects of individual parameter variations on model output. Results of this analysis are plotted in Figures 2-6 and described below.

Figure 2 displays model sensitivity to variations in the groundwater discharge to the Bush River. As noted above, the selected discharge rate of  $0.0136 \text{ m}^3/\text{sec}$  (0.48 cfs) corresponds to a dilution ratio of 159. However, higher discharge rates are likely to decrease the near-field dilution (Figure 2). For example, a near doubling of the discharge rate to  $0.025 \text{ m}^3/\text{sec}$  nearly halves the dilution to a ratio of only 88.

Likewise, Figure 3 represents the model sensitivity to the selected discharge length (i.e., the assumed length of the "line source"). As noted above, the discharge length is estimated to be 448 m (1,470 ft). This value assumes the extent of the lateral discharge to be the entire length of the Beach Point Peninsula fronting Bush River. However, a more conservative estimate of approximately half this length (i.e., 224 m, 735 ft) corresponds to a simulated near-field dilution ratio of 81. Also, a discharge of length of (152 m) 500 ft corresponds to a dilution ratio of 54. Overall, the dilution is somewhat sensitive to, and approximately linearly related to, this assumed discharge length.



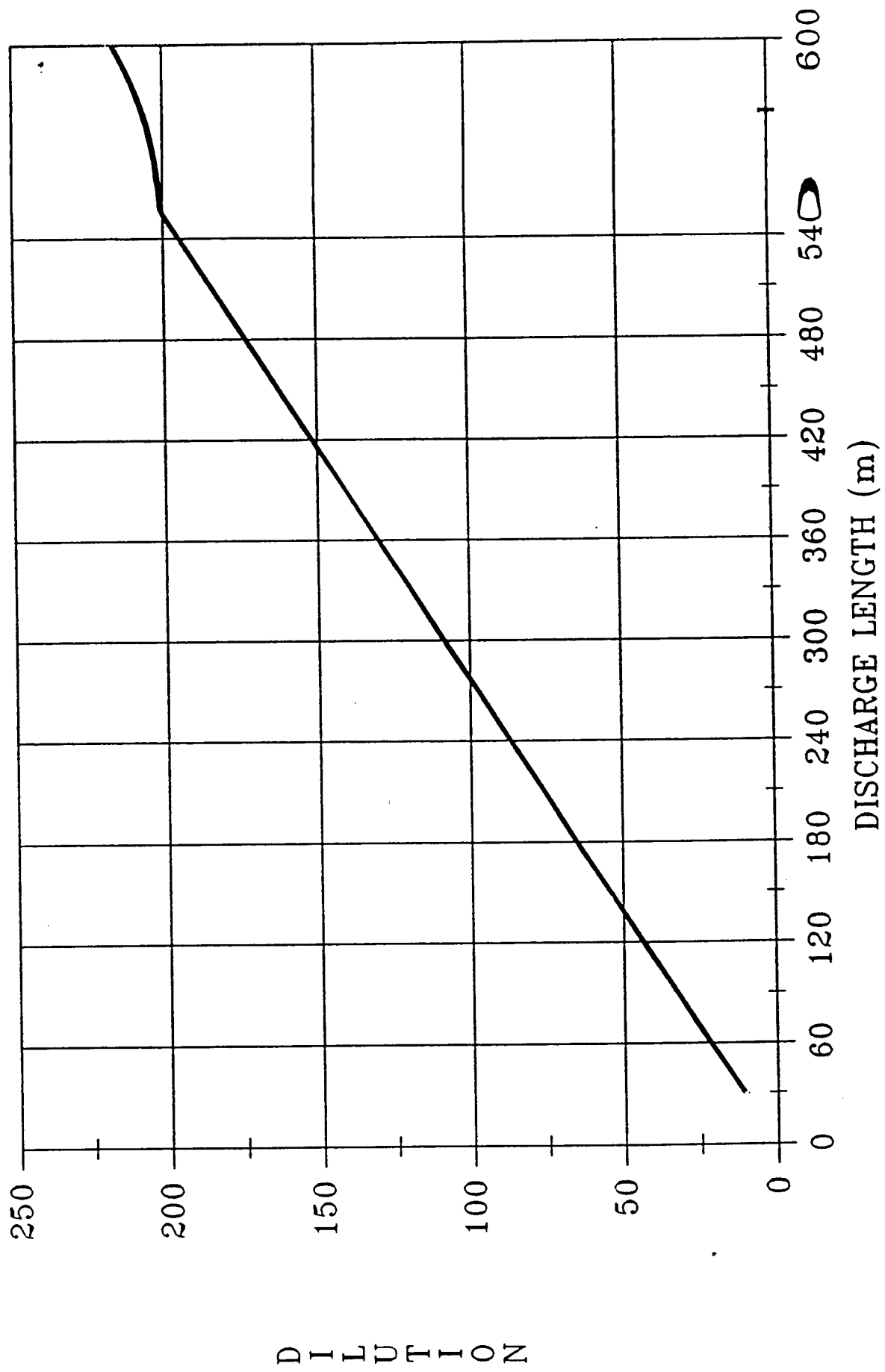
# SIMULATED DILUTION vs. DISCHARGE



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FIGURE 2

# DILUTION vs. DISCHARGE LENGTH



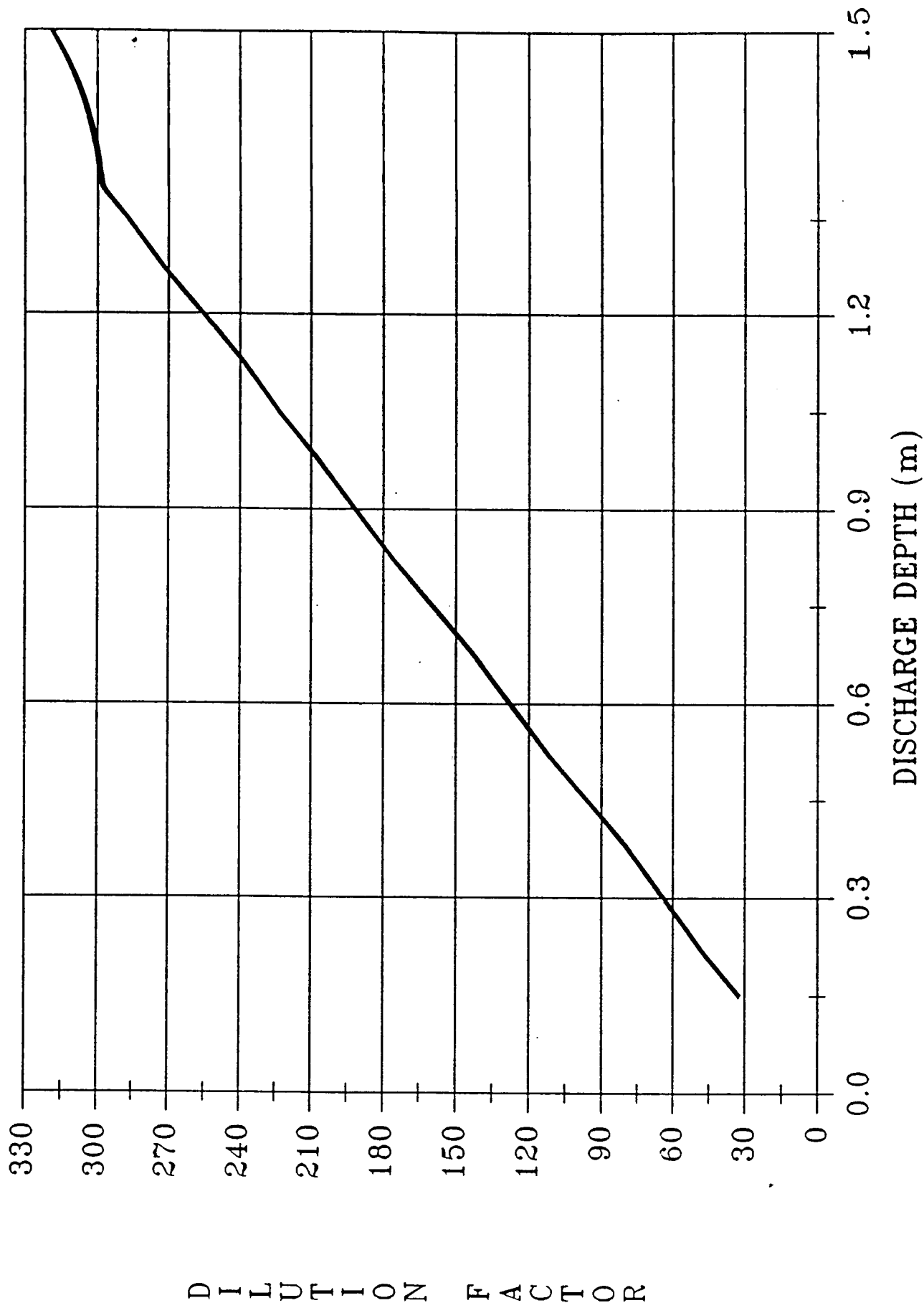
The model results are also somewhat dependent upon the assumed discharge depth. Figure 4 shows a nearly linear relation between the simulated dilution ratio and discharge depth. In this figure, note that the average water depth in the near field is approximately 1.5 m (5 ft). However, a conservative value of half this depth (i.e., 0.75 m or 2.5 ft) is used in all other simulations. This conservative assumption results in a dilution of 159 — nearly half of the corresponding dilution for a 1.5-ft-deep discharge (i.e., 319).

Typically, near-field models are sensitive to the ambient current speed. Figure 5 suggests that the adapted model is no exception. For example, the estimated tenth-percentile speed (i.e., 0.03 m/sec) corresponds to a dilution ratio of 159, while a speed of 0.02 m/sec corresponds to a dilution of 106. Thus, it is unlikely that uncertainties in the speed estimate will greatly enhance the computed dilution levels.

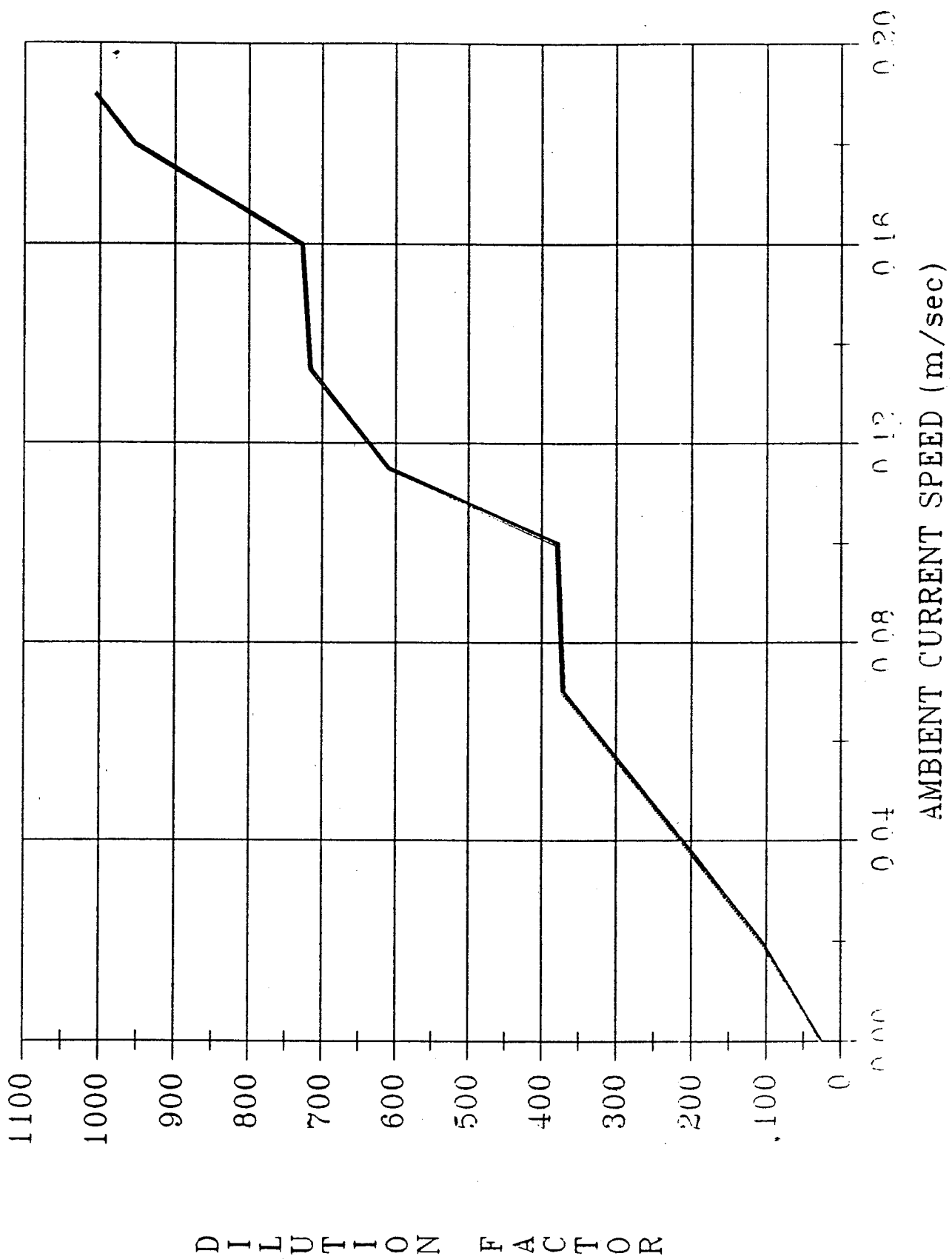
Finally, the adapted model assumes a Bush River salinity of 3 ppt. Figure 6 suggests that the model is relatively insensitive to other representative values for this parameter.

Based on the overall results of the model sensitivity analysis, a more conservative estimate of the near-field dilution factor would lie within the range of 54 to 159 for application of acute toxicity criteria. Similarly, a conservative estimate of the near-field dilution factor would lie within the range of 499 to 1,006 for application of chronic toxicity criteria.

# DILUTION vs. DISCHARGE DEPTH



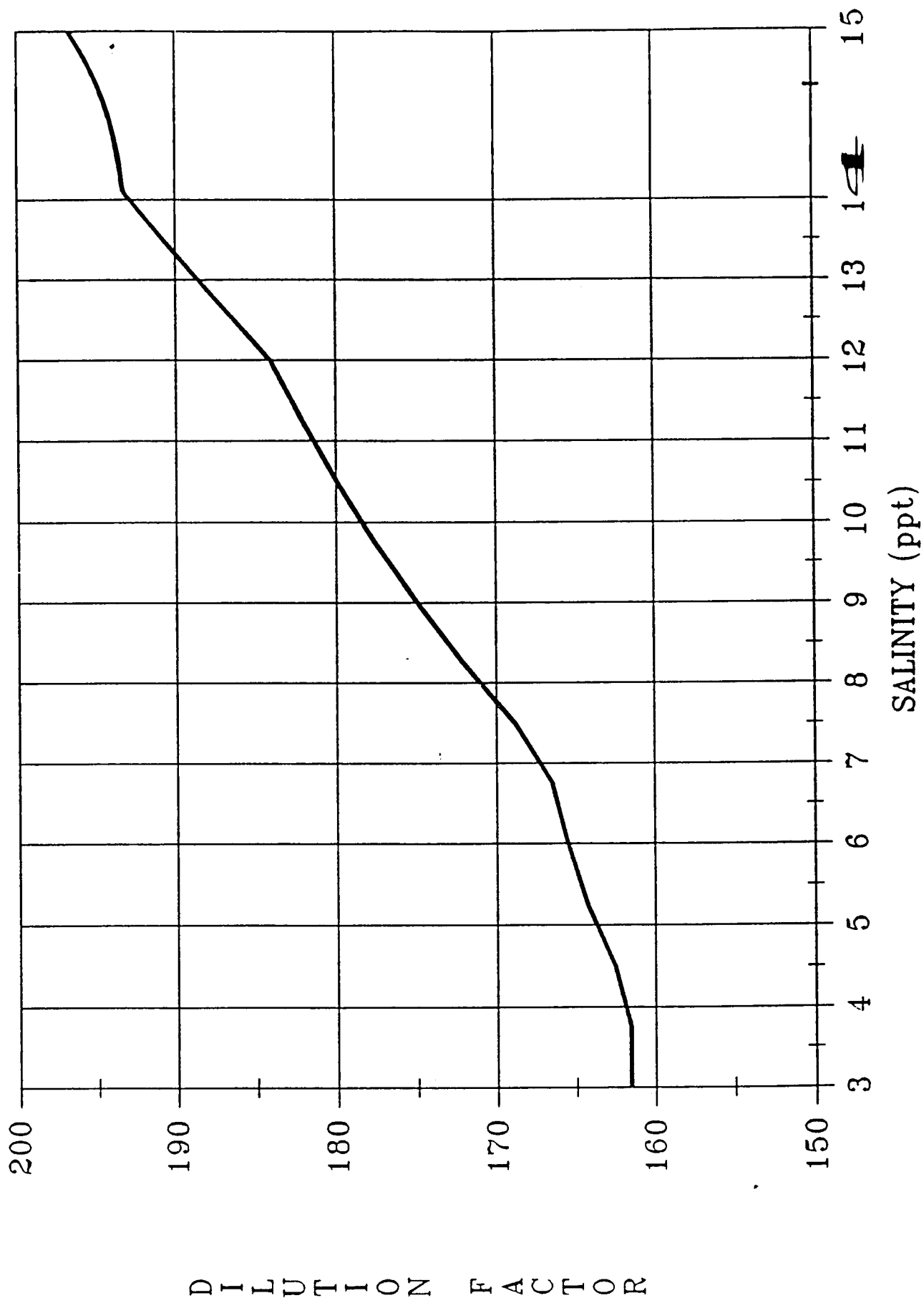
# SIMULATED DILUTION vs. AMBIENT CURRENT



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FIGURE 5

# DILUTION vs. AMBIENT SALINITY



### 3. FAR-FIELD DILUTION ESTIMATES

#### 3.1 Definitions

The Bush River receiving waters can be divided into two zones based on the physical mechanisms of mixing. In the near-field, rapid mixing is caused primarily by the discharge plume's buoyancy and initial discharge momentum, in combination with ambient currents. As noted above, near-field length scales are typically ones to tens of meters; near-field time scales are typically seconds to tens of minutes.

In the far-field, the plume is mixed passively by ambient processes such as turbulence and tidal dispersion. Far-field length scales are typically kilometer distances from the discharge site; far-field time scales are hours, days or more.

The following sections provide preliminary assessments of the far-field dilution (i.e., the flushing rate) in the Bush River Estuary. Methodologies for such techniques are documented in "Water Quality Assessment: a Screening Procedure for Toxic and Conventional Pollutants" (EPA/600/6-85/002b). Input required for these analyses includes the local tidal range, mean freshwater inflow and salinity data.

#### 3.2 Tidal Prism Method

The tidal prism method was first introduced by Ketchum (1951) and later elaborated (EPA, 1985). This method divides an estuary into a number of hypothetical segments having lengths of approximately one tidal excursion. Within each segment, complete mixing is assumed. Thus, the flushing flow for the  $i^{\text{th}}$  segment,  $Q_{fi}$ , is given by the tidal prism volume for that segment,  $P_i$ , divided by the dominant tidal period,  $T$  (i.e., 1 tidal cycle = 12.42 hours or 44,712 sec). The

corresponding residence time for that segment is computed as the total segment volume (i.e.,  $P_i + V_i$ , where  $V_i$  is the MLW volume) divided by the segment flushing

rate. The total segment residence time is the sum of all individual segment residence times.

Application of this method to the Bush River Estuary is illustrated in Table 3. In this application, the Bush River is divided into 6 hypothetical segments as delineated in the previous one-dimensional modeling study by Carter (1976). Typical segments are approximately 2-3 km long, comparable to one tidal excursion. Table 3 lists corresponding intertidal volumes and MLW (i.e., "subtidal") volumes for each segment. Table 3 also lists the computed segment "exchange ratio,"  $r_i$ , defined as the tidal prism,  $P_i$ , divided by the total segment volume,  $P_i + V_i$ . Thus, the computed residence time for the  $i^{\text{th}}$  segment (in units of tidal cycles) is simply the inverse of  $r_i$ . The tidal prism method calculations indicate that the total residence time for the Bush River is approximately 31 days. Moreover, the flushing time below the Beach Point site (i.e., for segments 2 and 1) is approximately 13 days (24.3 cycles). This suggests that the Bush River has limited "memory" of past discharges from the site. It should be noted, however, that the tidal prism method may underestimate the flushing time of an estuary since the selected segments are not, in reality, completely mixed.

Based on Table 3, the theoretical flushing rate at the Beach Point site,  $Q_{f2}$ , is given by the ratio  $P_2/T$  or approximately  $1.0 \times 10^6 \text{ m}^3$  per tidal cycle i.e., per 44,712 seconds). Thus, the corresponding far-field dilution is obtained by dividing this flushing rate by the assumed groundwater discharge flow,  $0.0136 \text{ m}^3/\text{sec}$  (see Eq. 6).



**TABLE 3: CALCULATION TABLE FOR TIDAL PRISM METHOD**

Segment Number	Segment Dimensions				Subtidal Water Volume, $V_i$ ( $m^3$ )	Intertidal Water Volume $P_i$ ( $m^3$ )	Segment Exchange Ratio $r_i$	Segment Flushing Time, $T_i$ (Tidal Cycles)
	Starting Distance Above Mouth (m)	Ending Distance Above Mouth (m)	Distance of Center Above Mouth (m)	Segment Length (m)				
6	18,810	16,110	17,460	2,700	$2.0 \times 10^6$	$4.3 \times 10^5$	0.18	5.6
5	15,310	11,910	13,610	3,400	$6.1 \times 10^6$	$8.7 \times 10^5$	0.12	8.3
4	11,910	9,260	10,585	2,650	$8.0 \times 10^6$	$8.5 \times 10^5$	0.10	10.0
3	9,260	6,560	7,910	2,700	$1.1 \times 10^7$	$9.5 \times 10^5$	0.08	12.5
2	6,560	3,700	5,130	2,860	$1.3 \times 10^7$	$1.0 \times 10^6$	0.07	14.3
1	3,700	0	1,850	3,700	$1.6 \times 10^7$	$1.7 \times 10^6$	0.10	10.0
							$\sum_{i=1}^n T_i =$	60.7 cycles (31.4 days)

This yields an estimated far-field dilution of 1,618. Again, note that this method likely overestimates this dilution since it assumes complete mixing within segments.

### 3.3 Fraction of Freshwater Method

This alternate method for estimating estuarine flushing times uses the freshwater content of estuarine segments as a tracer. That is, the "fraction of freshwater" for the  $i^{\text{th}}$  segment,  $f_i$ , is defined as the difference between the Bush River entrance salinity and the  $i^{\text{th}}$  segment salinity,  $S_s - S_i$ , divided by the entrance salinity,  $S_s$  (see Table 4, sixth column). The corresponding "freshwater volume,"  $W_i$ , for that segment is approximated by the fraction of freshwater,  $f_i$ , multiplied by the mean segment volume,  $V_i$ . Thus, in the steady state, the segment flushing time is simply the segment freshwater volume divided by the freshwater inflow,  $R$ . Again, the total residence time is obtained by summing the individual segment flushing times.

Application of this method to the Bush River Estuary is illustrated in Table 4. Note that the segmentation used for this method is the same as that employed in the previous section. The fraction-of-freshwater-method calculations estimate the total residence time for the Bush River as 57 days — somewhat longer than the tidal prism method estimate. However, the computed flushing time below the Beach Point site (i.e., for segments 2 and 1) is nearly the same — approximately 14 days (26.7 cycles). This also suggests that the Bush River has limited "memory" of past discharges from the site.

### 3.4 Previous Dye-Tracer Study Results

Far-field dilution also may be computed empirically based on field experiments. Accordingly, the dye-tracer data collected by Carter (1976) in the Bush River allows

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for such computations. Under spring (high-flow) conditions, Carter reports a steady dye dilution ratio of 267 (i.e., 61.4 ppb effluent concentration to 0.23 ppb measured).

Likewise, under fall (low-flow) conditions, Carter reports a dilution ratio of 315 (i.e., 50.5 ppb initial concentration to 0.16 ppb measured). Carter's data provides a more conservative estimate of the far-field dilution than the segmented (complete mixing) approaches described in sections 3.2 and 3.3. For this reason, and because it is based on direct measurements, the above-mentioned dilution ratios of 267 and 315 are adopted for use in the calculation of total near-field dilution.

### 3.5 Calculation of Total Near-Field Dilution

For a conservative constituent, the far-field, near-field and total near-field dilutions ( $S_f$ ,  $S_n$  and  $S_t$ , respectively) are defined (e.g., Fischer, 1979; Adams, 1990) as:

$$S_f = \frac{C_o - C_a}{C_f - C_a} \quad (1)$$

$$S_n = \frac{C_o - C_f}{C_n - C_f} \quad (2)$$

$$S_t = \frac{C_o - C_a}{C_n - C_a} \quad (3)$$

where  $C_o$ ,  $C_n$  and  $C_f$  are the constituent concentrations at the discharge, at the end of the near-field, and in the far-field, respectively. Note that in these definitions, the far-field concentration serves as a background concentration for the near-field in the same way that the ambient concentration serves as a background for the total near-field. These definitions may be combined to yield (Adams, 1990):

$$S_t = \frac{1}{\frac{1}{S_n} + \frac{1}{S_f} - \frac{1}{S_n S_f}} \quad (4)$$

or

$$\frac{1}{S_t} \sim \frac{1}{S_n} + \frac{1}{S_f} \quad (5)$$

This inverse sum indicates that the total dilution in the near field is always less than both the near-field and far-field dilutions. Moreover, the effectiveness of near-field mixing is always limited by the magnitude of the far-field mixing.

In the absence of other pollutant sources (i.e.,  $C_a=0$  in Eq. 1), the far-field dilution reduces to a ratio of either concentrations or flows (Adams, 1990):

$$S_f = \frac{C_o}{C_f} = \frac{Q_f}{Q_o} \quad (6)$$

where:  $C_o$  is the discharge concentration;  $C_f$  is the far-field concentration;  $Q_o$  is the discharge flow; and  $Q_f$  is the far-field "flushing flow" or downestuary transport rate (Officer, 1976). Note that the flushing flow is not a measurable flow rate, but is the equivalent rate at which mass is transported seaward.

*Based on an application of Eq. 5 with a value of  $S_n=50$ , the total near-field dilutions for acute toxicity conditions is calculated to be approximately 42 and 43 for under spring and fall conditions, respectively. Similarly, an application of Eq. 5 with a value of  $S_n=450$ , yield total near-field dilutions for chronic toxicity conditions of approximately 168 and 185 for under spring and fall conditions, respectively.*

### **3.6 Application of Dilution Factors to Toxics Discharge Data**

Using the above calculated dilution factors, near-field concentrations can be estimated for the parameters of interest. This estimate would be equal to the mean groundwater

concentration divided by the dilution factor. Thus, using the above dilution factor, a pollutant concentration of 42 ppb in the groundwater would be diluted to 1 ppb within

the near-field limits of the Bush River. In this manner, near-field concentrations for all detected groundwater constituents are calculated. These results concentrations are shown in Tables 5 and 6. An examination of these Table reveals that the expected near-field impacts will be near or below the method detection limit for most parameters. For such constituents, these analyses suggest that on-site contamination will not produce any discernable effect on the water quality of the Bush River.

**Table 5: Computed Dilutions of Volatile Organics (ug/l)**

Constituent	Groundwater Concentration	<u>Receiving-Water Concentration</u>	
		Acute*	Chronic**
Chlorobenzene	2	0.05	0.01
Chloroform	12	0.29	0.07
1,1-Dichloroethene	5	0.12	0.03
cis-1,2-Dichloroethene	640	15.24	3.81
1,1,1,2-Tetrachloroethane	3	0.07	0.02
1,1,2,2-Tetrachloroethane	17,000	404.76	101.19
Tetrachloroethene	90	2.14	0.54
1,1,2-Trichloroethane	110	2.62	0.65
Trichloroethene	1,600	38.10	9.52
Vinyl Chloride	2	0.05	0.01

\* Based on observed average concentration and dilution ratio of 42:1

\*\* Based on observed average concentration and dilution ratio of 168:1

**Table 6: Computed Dilutions of Heavy Metals (ug/l)**

Constituent	Groundwater Concentration	<u>Receiving-Water Concentration</u>	
		Acute*	Chronic**
Aluminum	1,500	35.71	8.93
Antimony	5	0.12	0.03
Arsenic	7	0.17	0.04
Beryllium	5	0.12	0.03
Boron	70	1.67	0.42
Cadmium	1.4	0.03	0.01
Chromium	5	0.12	0.03
Cobalt	110	2.62	0.65
Copper	8	0.19	0.05
Lead	5	0.12	0.03
Mercury	0.5	0.01	0.003
Molybdenum	40	0.95	0.24
Nickel	180	4.29	1.07
Selenium	5	0.12	0.03
Silver	1	0.02	0.006
Thallium	5	0.12	0.03
Tin	100	2.38	0.60
Zinc	310	7.38	1.85

\* Based on observed average concentration and dilution ratio of 42:1

\*\* Based on observed average concentration and dilution ratio of 168:1

#### 4. MIXING ZONE CONSIDERATIONS

The concept of mixing zones is normally applied in the case of wastewater facilities and power plants that discharge to tidal/coastal waterways via an outfall diffuser manifold. The following sections summarize Maryland's mixing zone regulations and explore their applicability to the subject groundwater discharges.

##### 4.1 Mixing Zone Regulations

A mixing zone is defined (COMAR 26.08.01.01B) as "an area contiguous to a discharge where surface water quality or groundwater quality does not have to meet: (a) all water quality criteria; or (b) all requirements otherwise applicable to the natural water." That is, pollutant concentrations within the mixing zone may exceed the specified water quality standards within a localized vicinity of the outfall. The dimensions of this zone are normally comparable to those associated with the initial dilution processes (e.g., 10-100 meters). Thus, marine organisms would only be exposed to concentrations exceeding the specified criteria for a brief period during a transit of the mixing zone (Muellenhoff et al., 1985). Of course, water quality criteria must still be met outside this zone. Moreover, as stated in COMAR 26.08.02.05A, mixing zones may be allowed "provided that the following requirements are met outside the mixing zone: (a) there shall be no interference with biological communities or populations of indigenous species to a degree which is damaging to the aquatic life or ecosystem; (b) there shall be no diminishing of other legitimate beneficial uses; (c) mixing zones may not form barriers to the migratory routes of aquatic life; (d) mixing zones shall be designated and located to protect surface waters and shallow water shoreline areas; (e) the general water



quality criteria set out in regulation .03B(1)-(3) of this chapter apply within this mixing zone."

Four types of numerical toxic substance criteria are promulgated by the MDE: (a) human health criteria through ingestion of public water supplies; (b) the wholesomeness of fish for human consumption; (c) fresh, estuarine, and salt water aquatic life criteria from *acute* toxicity impacts; and (d) fresh, estuarine, and salt water aquatic life criteria from *chronic* toxicity impacts. For the purpose of applying numerical toxic substance criteria, the Bush River Area (Sub-Basin 02-13-07) is classified by the MDE as "fresh water" (Comar 26.08.02.03-1B) and as "Use II" (shellfish harvesting waters). Corresponding toxic substances criteria for both ambient surface waters ("fresh water") and human health ("fish consumption") are listed in Table 7. Note that toxic criteria related to drinking water do not apply within shellfish harvesting waters.

The following regulations (COMAR 26.08.02.05D) pertain to the application of toxic substance *Chronic Criteria* for the protection of Aquatic Life. First, in terms of size, the Regulatory Mixing Zone (i.e., the mixing zone in which the Chronic Criteria are applied) may not exceed 10 percent of the cross-sectional area of the receiving waters. Also, *the Chronic Criteria are applied under flow conditions determined from site-specific data for the mean tide level, average tidal velocity, and, when appropriate, the design streamflow.* Based on the MDE's discretion, a plume-dilution study also may be required for the application of these criteria. In accordance with COMAR 26.08.02.06(a), conditions pertinent to the application of toxic substance *Chronic Criteria* are also relevant to the application of toxic substance *Human Health Criteria*.

**Table 7: Applicable Toxic Substances Criteria for the Bush River (ppb)**

Constituent	<u>Aquatic Life</u>		<u>Human Health</u>
	Acute	Chronic	Fish Consumption
Arsenic (tri)	360	190	
Cadmium	3.9	1.1	
Chromium (hex)	16	11	
Chromium (tri)	1700	210	3,433,000
Copper	18	12	
Cyanide	22	5.2	
Lead	82	3.2	
Mercury	2.4	0.012	0.146
Nickel	1,400	160	100
Selenium	20	5	
Silver	4.1	0.12	
Zinc	120	110	
Aldrin	3		0.00079
Benzidine			0.0053
1,1DCE			18.5
DDT	1.1	0.001	0.00024
Dieldrin	2.5	0.0019	0.00076
Endrin	0.18	0.0023	
Lindane	2	0.08	0.625
PCP	20	13	
PCB	2	0.014	0.00079
1,1,1TCA			1,030,000
Toxaphene	0.73	0.0002	0.0073
TCE			807
Tributyltin (TBT)		0.026	
2,3,7,8 TCDD (Dioxin)			0.0000012

The following regulations (COMAR 26.08.02.05C) pertain to the application of toxic substance *Acute Criteria* for the protection of Aquatic Life. Such acute criteria (for low-velocity dischargers) must be met within a short distance from the outfall using the most restrictive of the following conditions:

- (a) Within 10 percent of the distance (in any spatial direction) from the discharge to the edge of the Regulatory Mixing Zone (RMZ) used for the application of the chronic criteria.
- (b) Within a distance of 50 times the "discharge length scale" (i.e., 50 times the square root of the cross-sectional area of the discharge outlet).
- (c) Within a distance of 5 times the local water depth in any horizontal direction from the discharge outlet.

Thus, the region where the acute criteria are applied, sometimes called the "Toxic Dilution Zone" (TDZ), extends outward from the discharge to a distance no larger than any of the three lengths cited above. Moreover, the TDZ must not occupy more than 5 percent of the cross-sectional area of the receiving waters.

*Also, the acute criteria are applied under flow conditions determined from site-specific data for the mean low water elevation, the minimum daily averaged 1-hour tidal velocity and, when appropriate, design streamflow conditions. Such tidal stages are deemed "critical" (minimum-dilution) conditions.*

#### 4.2 Site Applicability

The regulatory conditions relevant to mixing zones were developed for outfall diffusers. Their application to an area-wide groundwater discharge is somewhat uncertain due to the unknown extent of this area. It seems likely that the discharge area is confined within the the RMZ, which for this case extends approximately 500 feet from the river

bank. However, the extent of the TDZ is more poorly defined as it partially depends on the configuration of the discharge. Thus, the applicability of the mixing zone concept must be further examined.

The concept of mixing zones provides an intermediate approach to the assessment of toxic constituent impacts. The two other approaches generally in use are "end of pipe" and "fully mixed". The "end of pipe" approach allows for zero dilution -- criteria are directly applied to the discharge water quality. This simplified approach yields the most stringent results which, in turn, most ensures the protection of aquatic biota. However, it may lack a physical or biological basis in terms of receiving water impacts. Thus, its results are not considered to be defensible -- it is effectively a non-technically based policy decision. Conversely, the "fully mixed" (or far-field) approach considers the total volume of the receiving water segment to be instantly available for the dilution of a discharge. This approach is generally far less stringent than the "end of pipe" approach. However, it may not adequately address biological impacts in the receiving water due to near-field conditions. The concept of mixing zones was evolved to address these limitations. Mixing zones allow consideration of the initial dilution process. This approach also protects aquatic life by limiting the potential for exposure to elevated concentrations to a minor portion of the waterway. As only a portion of the available dilution is considered in this approach, mixing zones provide a much more stringent basis for regulation than the "fully mixed" approach.

In the application of the mixing zone concept to the Bush River, it was necessary to conceptualize the area-wide groundwater discharge from the APG as a line source (diffuser). Due to this approach, potential impacts could be assessed in a technically defensible manner. However, this approach had a side effect of concentrating the

groundwater impact into a smaller area. *That is, this approach minimized the available near-field dilution and projected higher receiving water concentrations than would actually occur. Thus, the mixing zone analysis produced an overly conservative result. In the near-field, actual receiving water concentrations would be less than those projected due to more dispersed nature of the groundwater plume.* In the far-field, projected and actual receiving water concentrations should be comparable. However far-field concentrations would always be less than the near-field projections.

#### **4.3 Conformance with Criteria**

In Tables 8 and 9, the anticipated near-field receiving water concentrations are compared with the applicable water quality criteria. As shown in these Tables, no exceedences of these criteria are projected.

There will be a detectable impact on the receiving water concentrations due to volatile organic constituents (such as cis-1,2 dichloroethene; 1,1,2,2 tetrachloroethane; and trichloroethene). However, with the exception of trichloroethene (TCE), Maryland has not implemented criteria for these constituents.

**Table 8: Comparison of Projected Near-Field Concentration with  
Applicable Toxic Substances Acute Criteria (ppb)**

Constituent	Near-Field Concentration	Aquatic Life Acute Criteria
Arsenic (tri)	0.17 (total)	360
Cadmium	0.03	3.9
Chromium (hex)	0.12 (total)	16
Chromium (tri)		1700
Copper	0.19	18
Cyanide		22
Lead	0.12	82
Mercury	0.01	2.4
Nickel	4.29	1,400
Selenium	0.12	20
Silver	0.02	4.1
Zinc	7.38	120
DDT		1.1
Dieldrin		2.5
Endrin		0.18
Lindane		2
PCP		20
PCB		2
Toxaphene		0.73

**Table 8: Comparison of Projected Near-Field Concentration with  
Applicable Toxic Substances Chronic and Human-Health Criteria (ppb)**

Constituent	Near-Field Concentration	Aquatic Life Chronic Criteria	Human-Health Fish Consump.
Arsenic (tri)	0.04 (total)	190	
Cadmium	0.01	1.1	
Chromium (hex)	0.03 (total)	11	
Chromium (tri)		210	3,433,000
Copper	0.05	12	
Cyanide		5.2	
Lead	0.03	3.2	
Mercury	0.003	0.012	0.146
Nickel	1.07	160	100
Selenium	0.03	5	
Silver	0.006	0.12	
Zinc	1.85	110	
Aldrin			0.00079
Benzidine			0.0053
1,1DCE			18.5
DDT		0.001	0.00024
Dieldrin		0.0019	0.00076
Endrin		0.0023	
Lindane		0.08	0.625
PCP		13	
PCB		0.014	0.00079
1,1,1TCA			1,030,000
Toxaphene		0.0002	0.0073
TCE	9.52		807
Tributyltin (TBT)		0.026	
2,3,7,8 TCDD (Dioxin)			0.0000012

## 5. SUMMARY AND CONCLUSIONS

This study was initiated to assess the potential impact to the Bush River due to

contaminated groundwater emanating from the APG site in Harford County, Maryland. Towards this objective, an EPA-approved near-field model was adapted to the receiving-waters adjacent to the APG site. The model approach and input was developed to provide a conservative assessment of receiving water impacts. This analysis suggests a near-field dilution level of approximately 42:1 for the application of acute criteria and a near-field dilution level of approximately 168:1 for the application of chronic criteria. Thus, contaminants introduced into Bush River receiving-waters at a concentration of 42 ppb will be diluted locally to a concentration of approximately 1 ppb or less. By applying these dilution factors to the groundwater quality data from the APG site, near-field concentrations within the Bush River can be projected. As shown in Tables 8 and 9, none of the projected receiving water concentrations exceed Maryland's current acute or chronic criteria.

There will be a detectable impact on the receiving water concentrations of certain volatile organic constituents (such as cis-1,2 dichloroethene; 1,1,2,2 tetrachloroethane; and trichloroethene). Should Maryland enact more stringent criteria for these parameters, these results and conclusions must be re-evaluated. In such a case, a field study would be recommended. Such a study would include in-situ current measurement, dye release and tracking, CTD casts, and/or water quality data collection.



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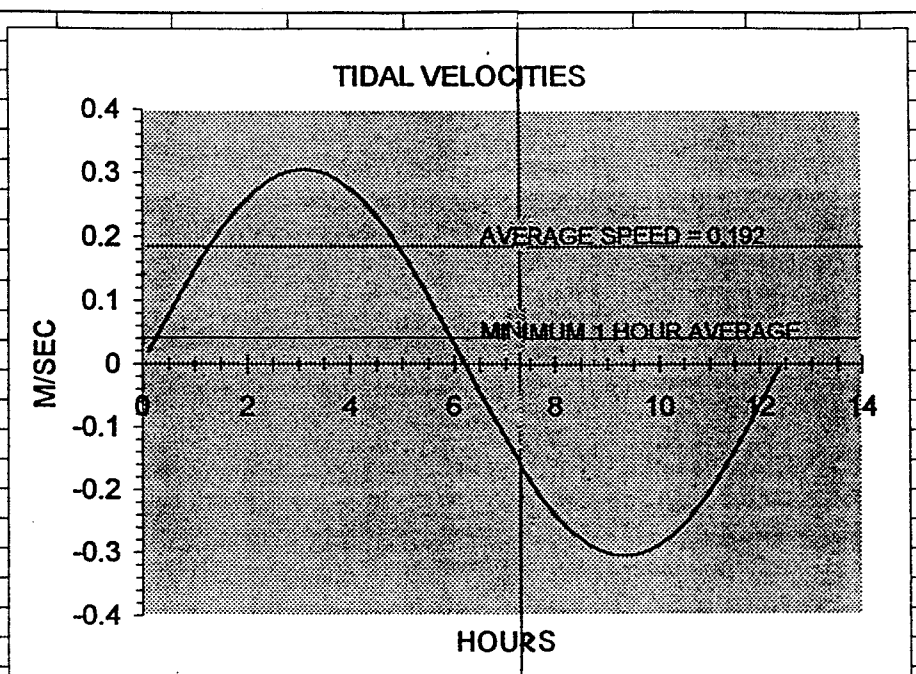
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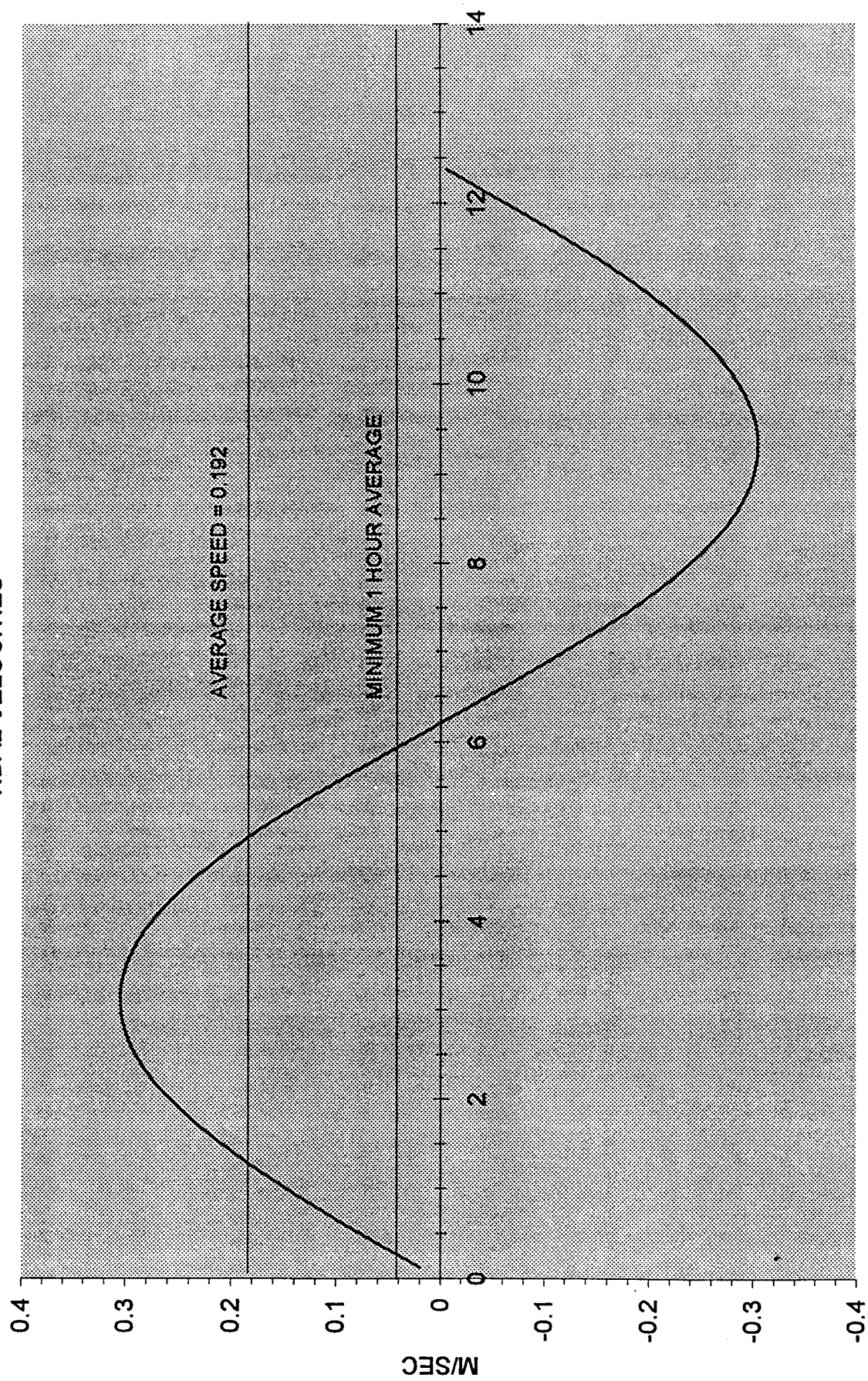
APPENDIX A

TIME (hours)	AMPL. (m)	
	0	0
0.125	0.019274205	0.019274
0.25	0.038471361	0.038471
0.375	0.057514728	0.057515
0.5	0.07632818	0.076328
0.625	0.094836512	0.094837
0.75	0.112965735	0.112966
0.875	0.130643379	0.130643
1	0.147798777	0.147799
1.125	0.164363351	0.164363
1.25	0.180270883	0.180271
1.375	0.195457785	0.195458
1.5	0.209863346	0.209863
1.625	0.22342998	0.22343
1.75	0.236103455	0.236103
1.875	0.247833108	0.247833
2	0.25857205	0.258572
2.125	0.268277354	0.268277
2.25	0.276910221	0.27691
2.375	0.284436141	0.284436
2.5	0.290825031	0.290825
2.625	0.296051351	0.296051
2.75	0.300094208	0.300094
2.875	0.302937441	0.302937
3	0.304569684	0.30457
3.125	0.304984413	0.304984
3.25	0.304179969	0.30418
3.375	0.302159569	0.30216
3.5	0.298931289	0.298931
3.625	0.294508033	0.294508
3.75	0.288907484	0.288907
3.875	0.282152031	0.282152
4	0.274268677	0.274269
4.125	0.265288936	0.265289
4.25	0.255248705	0.255249
4.375	0.24418812	0.244188
4.5	0.232151395	0.232151
4.625	0.219186648	0.219187
4.75	0.205345703	0.205346
4.875	0.190683891	0.190684
5	0.175259821	0.17526
5.125	0.159135153	0.159135
5.25	0.142374342	0.142374
5.375	0.125044392	0.125044
5.5	0.107214578	0.107215
5.625	0.088956175	0.088956
5.75	0.07034217	0.070342
5.875	0.051446972	0.051447
6	0.032346116	0.032346



6.125	0.013115957	0.013116				
6.25	-0.006166633	0.006167	0.043252			
6.375	-0.025424572	0.025425				
6.5	-0.044580877	0.044581				
6.625	-0.06355897	0.063559				
6.75	-0.082282986	0.082283				
6.875	-0.100678077	0.100678				
7	0.118670700	0.118671				
7.125	-0.136188955	0.136189				
7.25	-0.153162787	0.153163				
7.375	-0.169524352	0.169524				
7.5	-0.185208246	0.185208				
7.625	-0.200151771	0.200152				
7.75	-0.214295191	0.214295				
7.875	-0.227581968	0.227582				
8	-0.239958988	0.239959				
8.125	-0.251376774	0.251377				
8.25	-0.261789684	0.26179				
8.375	-0.271156092	0.271156				
8.5	-0.279438556	0.279439				
8.625	-0.286603967	0.286604				
8.75	-0.292623681	0.292624				
8.875	-0.297473635	0.297474				
9	-0.30113444	0.301134				
9.125	-0.303591463	0.303591				
9.25	-0.304834882	0.304835				
9.375	-0.304859727	0.30486				
9.5	-0.303665897	0.303666				
9.625	-0.301258166	0.301258				
9.75	-0.297646158	0.297646				
9.875	-0.292844312	0.292844				
10	-0.286871824	0.286872				
10.125	-0.279752568	0.279753				
10.25	-0.271515004	0.271515				
10.375	-0.262192061	0.262192				
10.5	-0.251821007	0.251821				
10.625	-0.240443302	0.240443				
10.75	-0.228104426	0.228104				
10.875	-0.214853706	0.214854				
11	-0.200744109	0.200744				
11.125	-0.18583204	0.185832				
11.25	-0.170177108	0.170177				
11.375	-0.153841896	0.153842				
11.5	-0.136891701	0.136892				
11.625	-0.119394284	0.119394				
11.75	-0.101419589	0.10142				
11.875	-0.083039469	0.083039				
12	-0.064327401	0.064327				
12.125	-0.045358184	0.045358				
12.25	-0.026207648	0.026208				
12.375	-0.006952348	0.006952				
AVERAGE SPEED=		0.192927				

# TIDAL VELOCITIES



HOURS

# Estimated Discharge Rates in the Surficial Aquifer Beach Point (Peninsula) Study Area

## Aberdeen Proving Ground-Edgewood Area, Maryland

**Assumptions:**  $V_{hor}$  measured in MW-33B.1 is continuous throughout the Surficial Aquifer at the Beach Point peninsula;  $V_{hor}$  orientation (flow direction) is constant with actual aquifer conditions over one complete tidal cycle (discounting short-term fluctuations due to tidal changes); the Surficial Aquifer at Beach Point is homogeneous, characterized by isotropic flow conditions.

MW-33B.1 (screened 41'-46'):  $V_{hor} = 0.89$  ft/day (61.8 NE)  
Average saturated thickness in Surficial Aquifer = 61.8'  
Length of Beach Point peninsula fronting Bush River = 1,470'  
Area of saturated Surficial Aquifer fronting Bush River = 90,882.7 ft<sup>2</sup>

1. If we assume  $V_{hor}$  is oriented perpendicular (orthogonal) to the Bush River frontage in the Surficial Aquifer, then the estimated groundwater discharge from the Surficial Aquifer to the Bush River side of Beach Point can be calculated as shown below:

$$\begin{aligned}\text{Estimated Discharge Rate} &= (V_{hor})(\text{Area of Surficial Aquifer X-Section fronting Bush River}) \\ &= (0.89 \text{ ft/day})(61.8')(1,470') \\ &= 80,852.9 \text{ ft}^3/\text{day} = 604,780.0 \text{ gallons/day}\end{aligned}$$

2. However, a more realistic estimation of discharge through the Surficial Aquifer along the Bush River involves using the directional component of  $V_{hor}$  orthogonal to the Bush River frontage. If this is performed, then the estimated groundwater discharge from the Surficial Aquifer to the Bush River side of Beach Point can be calculated as shown below:

$$\begin{aligned}\text{Estimated Discharge Rate} &= (V_{hor})(\text{Area of Surficial Aquifer X-Section fronting Bush River})(\text{component of } V_{hor} \text{ orthogonal to Bush River frontage}) \\ &= (0.89 \text{ ft/day})(61.8')(1,200.3')(\sin 23.8) + (0.89 \text{ ft/day})(61.8')(270.3') \\ &= 41,508.7 \text{ ft}^3/\text{day} = 310,484.8 \text{ gallons/day}\end{aligned}$$